Volume 14 Number 1

COMMONWEALTH OF AUSTRALIA

JOURNAL

OF

THE COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

FEBRUARY, 1941

Registered at the General Post Office, Melbourne,
for transmission by post as a periodical

C.400/41.

Council for Scientific and Industrial Research

314 Albert Street,
East Melbourne,
Victoria.

Volume 14 Number 1

COMMONWEALTH OF AUSTRALIA

JOURNAL

OF

THE COUNCIL FOR SCIENTIFIC

AND

INDUSTRIAL RESEARCH

FEBRUARY, 1941

Editor:
G. A. COOK, M.Sc., B.M.E.

Assistant Editor:
MARTIE E. HAMILTON, B.Sc.

Registered at the General Post Office, Melbourne,
for transmission by post as a periodical

H. E. Daw, Government Printer, Melbourne

C.400/41.

(PUBLISHED QUARTERLY)

Journal of the Council for Scientific and Industrial Research.

Vol. 14. FEBRUARY, 1941. No. 1.

CONTENTS.

(PUBLISHED QUARTERLY)

Journal of the Council for Scientific and Industrial Research.

Vol. 14. FEBRUARY, 1941. No. 1.

The Rabbito Defect of Butter.

*By E. G. Pont, M.Sc.Agr.**

1. Introduction.

The condition known as "Rabbito" in Australian butter is similar to, if not identical with, a type of deterioration that has attracted considerable attention in butter manufacturing countries during the last twenty years. Although appreciable progress has been made in the elucidation of the cause of the defect and the formulation of measures for its control, it is still a serious problem in some Australian States. This paper presents a review of the literature bearing upon rabbito and allied butter taints; its purpose is to define, if possible, the correct approach to the problem of their complete elimination or control.

2. Description of Defect.

The essential characteristic of the condition, which has been described under various names in different countries, is a taint suggesting the decomposition of protein. In general, the terms applied to it endeavour to convey this impression. Thus—"Rabbito" in Australia generally, "Decomposed" in New South Wales, "Putrid" in Denmark and the U.S.A., "Limburger" in the U.S.A., and "Foetid" in New Zealand. The term "Surface Taint" is commonly used also to describe the defect in Canada and the U.S.A. owing to its characteristic tendency to appear first on the outside surfaces of the butter.

The difficulties of evaluating and describing sensory impressions militate against an accurate and generally acceptable description of the condition. The strongest impression is gained by the olfactory sense. The odour may range from one that is faecal to one suggestive of meat in various stages of decay. In New South Wales it has been stated by Brown (1) to be frequently characterized by an odour suggesting bone-dust fertilizer. Different stages in the development of the defect or its association with other off conditions may give rise to varied impressions, but in all cases the suggestion of some form of putrefaction is common.

* An officer of the Council accommodated at the School of Dairy Technology. Werribee.

Although Cullity and Griffin (4) and Itzerott (9) have stated that the rabbito aroma appears first on the surface of the butter in common with the Canadian and American "surface taint," this does not appear to be an outstanding characteristic of the defect. More frequently, especially in older butters and print butters, it is not evident at the normal surface and only becomes apparent when a block of butter is broken across and fresh surfaces exposed. Under such conditions the aroma rapidly disappears and can be demonstrated only by revealing a new surface. The same authors refer to a "condensed milk" aroma as being a precursor to the rabbito taint. This is found only in the earliest stages of the defect, and the transition to the characteristic taint may be so rapid that this sweetish processed flavour is overlooked. In this respect it is of interest to note that "condensed milk" flavour in butter has been recognized as a distinct defect in New South Wales. Brown (1) refers to the condition in an article dealing generally with butter defects and specifically with a taint which appears to be more or less identical with that known now as rabbito. He distinguishes the two defects, however, and there is no suggestion that they are in any way related.

In all cases where the rabbito taint has developed to the point of recognition, the butter is severely degraded owing to the unacceptability of affected butter for table use.

3. Distribution and Occurrence.

Derby and Hammer (5) state that surface taint was first recognized as a definite butter defect in Canada in 1919. Gilruth (7) working with New Zealand butter reported the results of experiments with butter possessing a "foetid" aroma in 1899. A year later Eccles (6) in the U.S.A. gave an account of an investigation into an outbreak of "putrid" butter. Later in the 1920's, surface taint came to be regarded as a serious defect in Canadian and American butter, and Sadler and Vollum (18), Cordes (3), Macy (17), Hood and White (8), Shutt (20), and Mackay (16) reported the results of investigations dealing with the condition. About this time the defect in butter later known as "decomposed aroma" attracted attention in New South Wales. A description was given by Brown (1) who referred to it as a "disagreeable" aroma and reported the results of investigations. During the same period butter possessing the same general defect appeared commonly in Victoria and South and Western Australia, and the term "rabbito" first applied to it in Victoria became generally used in Australia in describing the condition.

Butter possessing the defect tends to be irregular or spasmodic in occurrence. It has been consistently reported to be unconfined to any particular district or class of cream. It may appear at a factory in one or two churnings, disappear, and then suddenly become evident a few weeks later. It may become epidemic and the whole of a factory's output may be consistently degraded. Frequently only one churning

from a particular vat may be affected. According to Cullity and Griffin (4) and also Brown (1), rabbito butter has been found to come from factories both satisfactory and unsatisfactory from the viewpoint of general sanitation. The occurrence of the taint is typically confined to summer months with high temperatures and flush production, but according to Cullity and Griffin (4) and Lock (12) it may occur during winter.

The rate at which rabbito and similar taints develop is dependent on the temperature. At comparatively high holding temperatures they may become evident in two to four days, whereas at 5°C. and lower a week or more may elapse before the butter deteriorates. Itzerott (10) states that experimental rabbito butters placed immediately in cold storage (12 to 15°F.) did not develop the defect after three months. The taint quickly appeared however when the butter was thawed out. On the other hand, Brown (1) reported that the condition studied in New South Wales sometimes developed in cold storage from butters which were apparently normal when first stored. In these cases it is possible that the normal thawing time to permit of butters being graded would be sufficient to allow the taint to develop.

Frequently butter which is normal in bulk becomes tainted rapidly when it is converted into prints, especially when a printing machine is used which subjects the butter to reworking. This may occur under conditions in which no contamination could be reasonably expected in the printing process.

4. Bacteriology of Affected Butters.

The nature of the defect has from the first suggested a bacterial origin, and most workers have confined themselves to this line of investigation. The results obtained from routine examinations indicate that rabbito and surface taint conditions are typically associated with high plate counts.

Cordes (3) and Macy (17) reported that surface taint butter invariably contained large numbers of bacteria and yeasts. Hood and White (8) in their report on Canadian surface taint butter stated that all the samples of affected butter examined in 1926 and 1927 gave unusually high bacterial and yeast counts and were characterized by large numbers of proteolytic organisms. Derby and Hammer (5) listed actual counts from surface taint butters. In samples taken from the surfaces of 35 tainted butters, one gave a count of 11,000 per gramme and the rest ranged from 450,000 to 300,000,000 per gramme. Plate counts from interior samples were on the whole lower. Two individual figures were 50,000 and 148,000 per gramme, the rest ranging from 500,000 to almost 30,000,000 per gramme. Loftus-Hills, Scharp, and Sewell (13) reported that rabbito butters invariably contained large numbers of organisms. A similar conclusion was given by Itzerott (9) who also emphasized the typically high numbers of gelatin-liquefying forms.

5. Causal Organisms.

The results of earlier studies suggested that *Pseudomonas fluorescens* was the causal organism. Gilruth with foetid butter (7), Eccles (6) with putrid butter, and Shutt (20) with surface taint were in agreement in this conclusion. On the other hand, Sadler and Cameron (19) reported the experimental production of surface taint with a spore former and an organism of the Escherichia-Aerobacter group in association. Macy believed that surface taint was brought about by a coccus type of organism in association with yeasts (17). All workers were in agreement with the fact that surface taint and similar butter generally contained very large numbers of organisms.

Pseudomonas fluorescens is characterized by such vigorous lipolytic activity that it is difficult to believe that this organism could be generally responsible for the taint in question. Derby and Hammer (5) reported that experimental butter inoculated with *Ps. fluorescens* consistently developed rancidity—there was no indication of surface taint. These workers in the same report recorded the isolation of a hitherto undescribed organism from surface taint butter which regularly produced the characteristic condition in butter made from inoculated cream. The organism was tentatively designated *Achromobacter putrefaciens.* Although emphasizing the importance of this particular organism in its relationship to surface taint, they stated that other distinct species were isolated which were capable of reproducing the taint experimentally. Hammer and co-workers (14, 15), in reports dealing with the effect of working butter on the development of micro-organisms, refer to unclassified cultures which produced putrid flavours.

Loftus-Hills, Scharp, and Sewell (13) in 1934 and 1935 reported the isolation of organisms similar to *Achr. putrefaciens* from rabbito butter in Victoria which were capable of reproducing the condition in experimental butters. Itzerott (9) has also consistently isolated organisms from Victorian rabbito butter which differ in no material respect from those described by Hammer and Derby. Claydon and Hammer (2) in 1939 reported the results of further experiments dealing with the relationship of *Achr. putrefaciens* to surface taint. They were able to isolate either the characteristic organism or variant strains from 81 per cent. of 58 samples of affected butter. They also offered satisfactory explanations for the comparative difficulty of isolating the organism and its failure to be recognized by earlier workers.

Description of Achromobacter putrefaciens.

For detailed descriptions the reader is referred to Derby and Hammer (5), Claydon and Hammer (2), and Bergey 5th Edition. In culture the organism is characterized by a prompt and complete reduction of litmus milk, strong liquefaction of gelatin, and general inertness towards sugars. It is non-lipolytic. Averaging 0.8μ by 2.5μ it is rod shaped in form, gram negative, non spore-forming, and actively motile with monotrichous flagella. Organisms isolated by Itzerott (10) were stated to be peritrichous. Cultures provided by this worker were examined by the author, and the flagellation was found to vary from peritrichous to monotrichous. Flagellation tended to be incomplete in the peritrichous strains; mostly only a few flagella, and in many cases only one, occurred on the sides of the organism. Agar colonies are

round, shining, with an entire edge and an internal granular structure. The growth is more or less colourless in the early stages, developing a reddish brown tint with age.

From the investigations of Derby and Hammer (5) it appeared that the organism was difficult to isolate owing to its presence in comparatively small numbers and its tendency to be outgrown by the more common types which occurred in great numbers in surface taint butter. Later Claydon and Hammer (2) emphasized the difficulty of isolating *Achr. putrefaciens* owing to its frequent failure to initiate colony growth on ordinary solid media. They developed a technique of isolation in which pasteurized cream was inoculated with a defective sample of butter. The cream was held overnight and churned, and the butter held until the characteristic taint developed. Small portions of the butter were then smeared on the surface of an agar plate. In some cases several churnings were necessary before the organism appeared in the smears. Only in a few cases and then generally in old butters was it found impossible to isolate the responsible organism by this means. Claydon and Hammer (2) stated that *Achr. putrefaciens* gave best growth on beef-infusion agar. Victorian workers have had considerable success in isolation with the use of nutrient gelatin as a medium.

Ecology of Achromobacter putrefaciens.

Apart from affected butter, water is the only source from which the organism has been at all consistently isolated. Claydon and Hammer (2) report a successful isolation from a factory water supply. Loftus Hills *et al.* (13) stated that the organisms responsible for rabbito butter were found in water supplies, churns, raw and pasteurized creams, and they considered water as its natural habitat. Itzerott (9) has succeeded in isolating the organism only from raw cream. In most cases, however, all attempts to locate the source of infection at a factory producing defective butter have failed. This result has been reported by Brown (1), Cullity and Griffin (4), Claydon and Hammer (2), and Itzerott (9) as well as earlier investigators. This condition provides one of the puzzling features of the trouble. It may possibly be explained by the previously mentioned inability of the organism to initiate colony growth on solid media reported by Claydon and Hammer (2). These authors stated that surface taint was experimentally produced by washing butter with water lightly inoculated with *Achr. putrefaciens;* under the conditions of the experiment the organisms could not be demonstrated in the wash water by plating methods, and the only positive evidence of its existence there lay in the appearance of the defect in the experimental butter.

Although in most cases the evidence is scarcely conclusive, many investigators are in agreement with water as the original source of contamination. Cullity and Griffin (4) quote an instance in which a factory was producing rabbito butter; the immediate source of infection was the churn. By adopting suitable remedial measures the trouble was overcome. Rabbito taint re-appeared several weeks later; a new water supply was resorted to and the defect finally disappeared. Brown (1) emphasized the importance of churn and general wood work contamination. Itzerott (9) concluded that foci of infection were developed in factories following contamination with cream and water containing the causal organism.

6. Effects of Acidity, Salt Concentration, and other Factors.

The influence of acidity and salt on the development of the causal organisms are naturally of interest as a possible means of exercising control over the defect. In general the results from a practical view point have not been promising. Brown (1) for instance stated that the "disagreeable" aroma was not confined to butter with any particular degree of acidity—at that time cream was neutralized to 0.2 per cent. acidity or lower in New South Wales. Itzerott (10) concluded that 0.2 per cent. acidity in cream was necessary before any appreciable effect upon the development of the taint was exercised. Derby and Hammer (5) found that the organism developed in litmus milk acidified with lactic acid up to 0.29 per cent. Claydon and Hammer (2) stated that the pH's of surface taint butters ranged from 5.8 to 6.8. In experimental unsalted butters it was found possible to produce the defect with a pH as low as 5.2.

The extent to which salt concentration controls the development of *Achr. putrefaciens* is to some degree related to the acidity. Itzerott (10) found that at higher acidities (0.2 per cent. and over) 1.4 per cent. of salt in the butter had a very strong inhibiting effect. He concluded that, with acidities ranging from 0.05 to 0.15 per cent., 1.7 per cent. of salt gave appreciable control, though it did not invariably prevent the taint from developing. Claydon and Hammer (2) found the salt concentrations of surface taint butters to range as high as 2.41 per cent. In their experiments they found that heavy salting did not control the defect unless working was thorough. In view of the well known effects of high acid and heavy salting in butter, it would appear that really effective control of rabbito and surface taint by this means could only be gained at the expense of serious impairment of keeping quality.

The possibilities of the use of starter in controlling surface taint have been investigated by Hammer and his co-workers (2, 5). They reported that in experimental butters, starter cultures added to the cream had a strong inhibitory effect. However, as they used large quantities of starter (from 5 to 10 per cent.), and in addition reported the occurrence of surface taint in factory produced starter butter, their results do not point directly to a practical means of effective control.

Achromobacter putrefaciens has been found to possess only a normal degree of resistance to heat. Derby and Hammer (5) stated that none of their cultures resisted five minutes' heating at 61.1°C. Itzerott (10) tested the heat resistance of his cultures over a range of temperatures; for a period of one minute's heating the death point was found to be 55° to 56°C. It is obvious that the organism has no special thermoduric or thermophilic characteristics which would enable it to survive the temperatures used in the pasteurization of cream (85° to 95°C.).

7. Relationship to Physical Structure of Butter.

The development of rabbito and surface taint has been stated to be definitely related to the physical structure of the butter. Cullity and Griffin (4), Lock (12), and Itzerott (9) report that the condition is more frequent and more serious in poorly-worked butters showing open

texture and free moisture. They emphasize the importance of thorough working in controlling the defect. The influence of butter structure on bacterial development is well known; the reasons for the frequent development of rabbito taint in reworked or printed butter however are not so obvious. Cullity and Griffin (4) quote interesting cases in which the reworking of apparently sound butter rapidly brought about the appearance of the defect.

Exhaustive reference to literature treating the influence of butter structure on bacterial development would unnecessarily extend the scope of this article. It is sufficient to emphasize the general conclusion on which various investigators are in agreement—that the ability of organisms to develop in butter decreases as the working time increases. This is undoubtedly due to the greater degree of dispersion of moisture in well worked as compared with underworked butter. Further, any factor which tends to cause an aggregation or coalescence of moisture droplets after working directly favours bacterial multiplication. Thus Knudsen and Jensen (11) found that in some cases development of organisms was much more rapid in lightly salted than unsalted butter with the same degree of working. This was due to the formation of larger water droplets owing to the moisture attracting power of the salt.

Long and Hammer (14) examined the effect of moisture distribution on the growth of specific organisms including *Achr. putrefaciens* in unsalted butter. They found that with this organism spoilage usually occurred in one to two days with under-working, whilst butter thoroughly worked was still sound after seven days and in one trial after 21 days. The same authors in a later paper (15) reported the results of an inquiry into the effects of reworking butter about three days after manufacture. The experimental butter was unsalted and was inoculated with various organisms including *Achr. putrefaciens*. They stated that the growth rates of the organisms used frequently increased, and the time taken for defects to appear generally decreased, with reworking. The effect of reworking was related to the extent of original working; with underworked butter subsequent reworking had a pronounced stimulating effect upon bacterial growth and the development of taints. The same investigators pointed out that the printing of butter in equipment subjecting it to reworking tended to aggregate moisture droplets. In this type of printing machine there is actually a considerable loss of moisture unless the butter has been thoroughly worked beforehand. The effects of reworking generally are almost certainly due, in part at least, to this aggregating effect upon the water droplets.

These conclusions have direct application to the question of rabbito taint in underworked or reworked butter. It must be emphasized however that in no case has it been demonstrated that thorough working alone will entirely prevent the taint developing providing other essential conditions, i.e. adequate infection and temperature are present. They do not explain also why the printing of butter by means of wire cutting machines may also hasten the development of rabbito taint. In this case the butter is not subjected to reworking in the accepted sense of the term, and some other factor such as aeration appears to be involved.

8. Summary and Conclusions.

It is impossible to eliminate surmise from many aspects of the rabbito and surface taint problem owing to the scarcity of direct experimental evidence. The following conclusions however appear to be justified:—

1. Rabbito taint in Australian butter and the putrid and surface taints in Canadian and United States of America butter are essentially the same defects.

2. These defects have only become widespread in comparatively recent years, and their occurrence has coincided with the development of a low acid mildly salted type of butter.

3. None of the characteristics of the defective condition are inconsistent with the theory of a biological causative agency.

4. Rabbito and surface taints are typically associated with highly excessive numbers of micro-organisms.

5. One organism in particular, designated *Achromobacter putrefaciens,* has been found to be constantly though not invariably present in both surface taint and rabbito butters. It is capable of reproducing the typical taint under experimental conditions.

6. Other undescribed organisms have been encountered, though less frequently, which are capable of reproducing the taint in experimental butters.

7. Although direct evidence is far from conclusive, the original source of infection in the butter factory appears to be the water supply. Secondary, and in many cases more serious, foci of infection may be set up in churns and other equipment. Woodwork is most important in this respect.

8. Essential factors in the production of the defect are adequate infection and suitable temperatures for growth of causal organisms.

9. Heavy salting, high acidities (within the range of safe limits from the viewpoint of keeping quality), thorough working, and efficient manufacture generally assist in minimizing or controlling the defect. From the evidence available these factors cannot be relied upon for absolute control in the presence of the essential conditions given in the previous paragraph.

10. Most investigators are in agreement on the following measures for control in roughly the order of their importance.

- (*a*) Purification of water supplies by chlorination or filtration.
- (*b*) Elimination of secondary sources of infection particularly in churns and woodwork generally. In many cases complete replacement of wooden parts of infected churns has been found necessary.
- (*c*) Attention to factors concerned with satisfactory physical condition of butter. Thorough working is stressed.
- (*d*) Adequate pasteurization temperatures.
- (*e*) Increased salt concentrations—up to 1.7 per cent., and higher acidities at churning—up to 0.15 per cent.

Puzzling or undetermined characteristics of the rabbito defect which invite further research are:—

(1) The irregular and spasmodic manner of its occurrence.

(2) The fleeting and transient nature of the characteristic aroma.

(3) The difficulty of defining and eliminating sources of infection.

(4) The frequent marked degradation of quality effected by apparently small numbers of the causal organisms.

(5) The development of the organisms concerned together with the characteristic taint in relation to the air content of butter.

(6) The influence of chemical and physical factors generally.

The justification, from the practical standpoint, for further research is more difficult to determine. There are strong indications that the defect is largely the outcome of conditions of production which have failed to keep pace with the higher standards demanded by the type of butter manufactured to-day.

On the other hand it is not clear whether the reported high plate counts of rabbito and surface taint samples refer to bulk butter, or print butter taken from retail trade channels. In the latter case high bacterial counts are not necessarily indicative of unsatisfactory manufacturing hygiene; they may to some extent be a reflection of the conditions of temperature and handling which butter is expected to stand up to without undue deterioration. Under the same conditions the incidence of specific destructive organisms like *Achromobacter putrefaciens* is much more important in determining keeping quality than total or group counts.

The problem of complete control is centred upon the total elimination of sources of infection in the factory or the development of measures designed to inhibit the organism or its associated taint in the butter. The admitted imperfection of our knowledge relating to more than one aspect of the rabbito and surface taint defects at least gives colour to possibilities in both directions.

9. References.

1. Brown, A. M.—New South Wales Butter Quality. *Agric. Gaz. N.S.W.* **39**: 843, 1928.

2. Claydon, T. J., and Hammer, B. W.—Relationship of *Achromobacter putrefaciens* to Putrid Defect of Butter. Res. Bull. Iowa Agric. Expt. Station No. 267, Dec. 1939.

3. Cordes, W. A.—"A Study of Surface Taint in Butter." Blue Valley Res. Lab. 1923-1927. Quoted from Derby and Hammer (see Ref. 5).

4. Cullity, M., and Griffin, D. G.—Rabbito or Surface Taint in Butter. *J. Dept. Agric. W. Aust.* **15** (2): 135, June 1938.

5. Derby, H. A., and Hammer, B. W.—Bacteriological Studies on Surface Taint Butter. Iowa Agric. Expt. Stat. Res. Bull. No. 145, 1931.

6. Eccles, C. H.—A Case of Putrid Butter. Iowa Agric. Expt. St. Bull. 59, p. 50, 1901.

7. Gilruth, J. A.—"Bacteriological Examinations for Dairy Science." N.Z. Dept. of Agric. 7th Report, p. 89, 1899. Quoted from Derby and Hammer (Ref. 5).

8. Hood, E. G., and White, A. H.—Surface Taint Butter. Canadian Dept. of Agric. Pamph. No. 91. New Series. 1928.

9. Itzerott, G.—"The Rabitto Defect of Butter and its Control." *J. Dept. Agric. Vict.* 39: 1, January, 1941.

10. Itzerott, G.—Unpublished Reports.

11. Knudsen, S., and Jensen, M. (1930).—Quoted from Long and Hammer. (See Ref. 15.)

12. Lock, J.—J. S. Aust. Dairy Factory Man. and Sec. Assoc., 1931.

13. Loftus Hills, G., Scharp, L. R., and Sewell, H. C.—J. Vict. Dairy Factory Man. and Sec. Assoc., 1934 and 1935.

14. Long, H. F., and Hammer, B. W.—The Effect of Moisture Dispersion in Butter on the Growth of Bacteria. Iowa Agric. Expt. St. Res. Bull. No. 246, 1938.

15. Long, H. F., and Hammer, B. W.—The Effect of Reworking Butter on the Growth of Bacteria. Iowa Agric Expt. St. Res. Bull. No. 263, 1939.

16. Mackay, K. G.—Canadian Dept. of Agric. Quoted from Derby and Hammer. (Ref. 5.)

17. Macy, H.—Cited in "The Butter Industry." 2nd. Ed. p. 493, by O. F. Hunziker.

18. Sadler, W., and Vollum, R. L.—The Relation of Bacteria to the Quality of Graded Butter. Nat. Res. Council Canada. Rept. 16. Ottawa, 1926.

19. Sadler, W., and Cameron.—Quoted from Derby and Hammer. (Ref. 5.)

20. Shutt, D. B.—Contaminated Water as a Source of Surface Flavour in Butter. *Sci. Agric.* 9: 316, 1929.

Does a Study of Wood Anatomy Have Practical Value?

*By H. E. Dadswell, D.Sc., A.A.C.I.**

The great majority of people may be pardoned for being completely ignorant of the little-known science of wood anatomy. In fact, throughout the world, there are probably no more than 200 scientists who claim to have any deep knowledge of the subject. Yet there is a definite practical need for the investigation of the anatomy of wood—a need that is not fully appreciated even by many people in the timber trade itself. Therefore it is well to consider just what is involved in the study of such a subject and what practical results are obtained.

In the first place, it should be realized that a piece of wood is an exceedingly complex piece of material, and that even though all woods seem to be somewhat alike superficially, they are often quite different anatomically. Every carpenter and cabinet worker knows that timbers differ greatly in the way they work, every person purchasing furniture or arranging for wooden interior fittings in a newly-built house prefers some timbers to others because of some particular quality, every builder and engineer knows that one timber is stronger than another, and so on; very few, however, realize that these differences are due to variations in the arrangement and contents of the individual cells that make up the material. The structure of one timber will differ in some way from that of every other timber; all pieces of the same timber have similar structure. Thus it may be said that each individual timber has its own particular basic pattern which is reproduced in all the material cut from a given tree and from any other tree of that particular timber. Therefore, in a study of the anatomy of wood, it has been essential to examine various timbers of the world and make a record of the individual pattern of each one. This has been carried out by wood anatomists in various countries making a particular study of the timbers of their own countries and publishing the results. When, as has been done, a standard list of descriptive terms and definitions is followed, it is possible for workers in one country to use the results obtained elsewhere. Much has been accomplished in the furthering of this interchange of information by the International Association of Wood Anatomists. In Australia, the Section of Wood Structure of the Division of Forest Products has been working since 1931 on the investigation of Australian and Pacific Island timbers, recording details of structure and classifying differences. It has also been building up a reference collection of authentic Australian timbers as well as timbers from other parts of the world and preparing from these the necessary thin sections used in microscopic examinations.

Thus the well-informed wood anatomist has available a record of the structural details of the majority of the important commercial timbers. He is constantly adding to this record by the continual

* Officer-in-charge, Section of Wood Anatomy, Division of Forest Products.

investigation of material as it is obtained. The record of any one particular timber is never considered complete unless material from numerous specimens from different trees has been subjected to microscopic examination. Only by such means can the small variation in the basic pattern of a timber be adequately covered. The task of the wood anatomist is rendered very complex when, as is often the case, various commercial timbers belong to the one botanical genus. One need only to consider our own genus *Eucalyptus,* from which there may be derived up to 100 commercial or potentially commercial timbers, to understand the problems which confront the investigator. All these various eucalypts, while differing in structure on some points, show a distinct similarity which makes the task of determining exact points of difference an extremely difficult one. However, the practical value of these timbers makes such work necessary.

After the study of the basic pattern of all the timbers of a country or a locality, the next procedure is to develop keys for their identification so that when confronted by a piece of wood, and the question "What is it?", something more than an intelligent guess will be the reply. It may well be asked, how necessary is all this investigational work, why does any one have to know the exact identity of a piece of timber, in what way does the knowledge of the basic pattern of various timbers help the practical man? The answers to these questions may be found in the following statement of facts. The number of timber identifications handled by the Section of Wood Structure of the Division of Forest Products averages 40 a month, or approximately two every working day. These are brought in by (*a*) various Commonwealth and State Government Departments who are timber users, (*b*) members of the timber industry, and (*c*) private individuals. In addition, the other Sections of the Division require numerous identifications from time to time in the course of their work. Timbers thus received may have come from any part of the world and the Section of Wood Structure has to be able to place them and identify them. It has been found that more than one-third of these identifications are eucalypts of one kind or another.

From a survey of the inquiries of the past few years, it would seem that reasons underlying such identification requests are numerous and vary greatly. Some of the occasions on which timber identifications are required are as follows:—

(*a*) When a particular timber in use has proved eminently satisfactory, but it is known only by a trade name which may be insufficient to identify it accurately.

(*b*) When timbers very similar in appearance are quite different in properties and the purchaser wishes to be certain that he is receiving the timber specified.

(*c*) When it is necessary to obtain a substitute with similar properties.

(*d*) When a timber is known only by a local name or is of doubtful identity.

(*e*) When, in research work, abnormal results are encountered.

(*f*) When it is only a matter of interest.

Naturally, some identifications can be made at a glance, unfortunately some take more time than they are worth, since they may be classed under (*f*) above, and more unfortunately still, in a few instances, it is not possible to make a definite identification. This may be due to the fact that information is lacking or there is no authentic material for comparison, or may be due to the fact that the botanical identity of the species from which the timber is derived has not been settled. The last alternative is often the case with samples of Island timbers which have been sent in for identification. In such cases the examination of wood structure will often reveal the botanical family to which the timber belongs and give some hint as to the genus. It will be seen from the above, however, that the painstaking work involved in studying and recording the patterns of various timbers does have definite practical value, and that there is still a definite need for keeping the available information up to date and building up a reference collection of authentic material.

However, the study of wood anatomy with the object of developing and perfecting methods of identification is not the only goal of the wood anatomist. He must also investigate the structure of wood in relation to its properties. As indicated above, the structure of any particular species follows a well-defined pattern, but there are always some differences in structure within a species that are traceable to conditions of growth which, in turn, are reflected in the physical and mechanical properties of the wood. For example, gross variations in structure as in the number of growth rings per inch, or in the width of latewood, or in the density of the wood, all have some bearing on the mechanical properties of the wood. These relationships have been fully investigated for numerous species, and it has been established that selection of timber for definite purposes where quality is essential can be greatly assisted by using the knowledge gained by such investigations. To date, little of such information is available concerning Australian species, but the work is being carried out rapidly at the present time. It involves the examination of the structure of all the test specimens used in the determination of the mechanical properties of a species. When some 40 logs from 30 trees are examined from every species, it will be realized just what such an examination entails. However, such work must be carried out in order to learn what are the relationships between structure and strength in the various species under investigation.

Abnormal growth conditions also seriously affect the properties of timber, and the structure of the wood formed under such conditions must be thoroughly investigated. Work of recent years has shown that certain of the unusual properties of timber may be traced to the fact that abnormal wood is present. Such abnormal wood has been referred to in general as "reaction wood," and its function seems to be mainly to assist a tree to overcome disabilities during growth. For example, a leaning tree tends to bring itself into a more vertical position by laying down "reaction wood," or such wood is formed in a tree trying to maintain its position towards the light in spite of the influence of gravity. Naturally, since "reaction wood" is laid down during some abnormal conditions in the life of the tree, it may be expected to behave somewhat differently to normal wood. The main

differences that have been observed are in density, longitudinal shrinkage, and certain mechanical properties. Differences are also found in the structure of the wood. These may be detected by visual inspection, but can only certainly be discovered by microscopic examination. Thus the wood anatomist must know the details of difference between " reaction wood " and normal wood in order to determine the limits of both, and as a result of his observations it is possible, when necessary, to select timber free from wood which has undesirable properties.

" Reaction wood " in coniferous woods is usually referred to as " compression wood," as it is found on the lower or compression side of a leaning stem. Often it is easily recognizable on the end sections of logs because of the formation of wide bands of wood darker in colour than the neighbouring normal wood. However, it may also be quite indistinguishable from normal wood and only microscopic examination will reveal it. " Reaction wood " in hardwoods (pored timbers) is developed on the upper or tension side of leaning stems and has been called " tension wood." This type of wood is of fairly wide occurrence, but is not easy to detect visually in a log, although in converted timber a certain abnormal condition having the appearance of woolliness of the grain is an indication of its presence. By microscopic examination, and in some instances a suitable staining technique, it is possible to determine its extent and distribution. The influence of both these types of " reaction wood " on the properties of a number of Australian timbers is now being investigated. As some of these particular timbers are possible aeroplane timbers, it is essential for the wood anatomist to obtain all the knowledge possible so that suitable methods of selection can be devised.

" Brittle heart," a defect frequently found near the centre of many Australian trees and for that matter most large tropical trees, has also been investigated in order to find what point of structure, if any, is connected with it. Brittle wood must be avoided in the selection of material for purposes where strength in impact is required. The wood anatomist has been able to demonstrate the immediate cause of the brittleness, namely, the presence of minute compression failures in the walls of the individual cells, and as a result, a test has been developed for indicating " brittle heart."

Unfortunately, the word anatomist cannot yet explain all the variations in the properties of timber. On the basis of variations in the gross structure, in the finer details of cell arrangement, and on the basis of the presence of abnormal " reaction wood," it is possible to account for little more than 60 per cent. of the variation in properties. It has become more and more evident that the investigations must be extended to the actual composition of the cell walls themselves and to the actual bonding material. It should be realized that the cell wall contains the greater part of the actual solid material of the wood, and that when the bonding material is removed by suitable although drastic chemical treatment, the individual cells or fibres are separated from each other. In the examination of these details of the structure of wood, the wood anatomist must have the assistance of both the chemist and physicist, for only by their co-operation can the physico-chemical

composition of the cell wall be elucidated. In the past few years enough work has been done to indicate that the chemical composition of the cell wall does have some relation to the strength and properties of the timbers. As a result of this work, it is possible to predict whether one timber will be stronger or weaker in certain respects than another of the same specific gravity. Further, the knowledge of the nature and location of the bonding materials holding the fibres together is of intense interest to the pulping industry, whose one aim is to isolate individual fibres from wood, as easily as possible, and in as high a yield as possible.

There is still a tremendous amount of investigational work before the wood anatomist. Only the fringe of the problem has been tackled as yet, and there is no reason to doubt that when he is armed with further information the wood anatomist will be able to suggest many ways for the more efficient use of different timbers.

The Internal Lacquering of Tinplate Containers For Foods.

II. The Prevention of Black Staining by the use of Lacquers and Protective Films.

By J. F. Kefford, M.Sc., A.I.C., and L. J. Lynch, B.Sc.Agr.**

Summary.

The prevention of black staining in food cans has been investigated by packing certain meat, fish, vegetable, and dairy products in cans subjected to the following treatments:—

1. Internal lacquering with commercial "sulphur-resisting" lacquers.
2. Deposition of anodic oxide films within the can by electrolysis in alkaline media.
3. Simultaneous deposition of a lacquer film and an oxide film by electrolysis of a lacquer emulsified in sodium aluminate solution.
4. Chemical formation of a protective film by immersion in a hot, alkaline, oxidizing phosphate medium.

The latter method, in particular, gave excellent protection against black staining by all the products tested.

1. Introduction.

Some foodstuffs, notably meat and fish products (8, 10, 13, 14), certain vegetables (9, 12), and dairy products (11), when packed in plain cans produce a black stain on the interior of the can. The stain has been found to be stannic sulphide or iron sulphide formed by the action of sulphide ions presumably liberated by the decomposition of the sulphur-containing amino-acids of the proteins in the canned material.

Stannic sulphide occurs as a film closely adherent to the surface of the can and is responsible for types of staining variously described as "purpling," "bronzing," &c. These conditions are usually associated with a general etching of the tin surface known as "feathering" or "spangling."

Iron sulphide is generally formed as a loose deposit at points where the steel base plate is exposed and may appear in the food product on its removal from the can.

From the consumer's point of view, the latter is the more objectionable form of black staining; but even when, as in most cases, the contents are not stained, the blackened interior of the can detracts from the appeal of the canned product.

Several methods have been proposed for the prevention of black-staining in food cans. The common practice, at present, is to lacquer the cans internally with one of the so-called "sulphur-resisting" lacquers. These lacquers were originally developed by Bohart (3) to prevent black-staining in canned sweet corn and contain, in suspension, a compound of a metal which forms a white sulphide. The sulphide ions

* An officer of the Division of Food Preservation and Transport.

from the canned product then form a white sulphide in the lacquer film instead of a black sulphide of tin or iron on the surface of the can. Zinc oxide is commonly incorporated in lacquers for this purpose.

More recently, patents have been granted for certain methods which depend upon the formation on the internal surface of the can of an invisible, chemically-passive film protecting the underlying metal against the action of sulphide ions and inhibiting black staining. One patent (6) describes the production of an anodic film of tin oxide within the can by electrolysis in an alkaline medium, e.g. dilute ammonia solution. In a modification of this method (7, 15), the electrolyte is a solution of sodium aluminate, and the tin oxide film which is formed in this alkaline medium is reinforced by the deposition of a film of alumina. The action of the alumina film in preventing black staining may merely afford mechanical protection or may depend on the formation of white aluminium sulphide instead of the black sulphides of the metals of the can. The same patent describes a process in which a lacquer is emulsified in the sodium aluminate solution, and, on electrolysis, a lacquer film and a composite oxide film are deposited simultaneously.

The International Tin Research and Development Council has recently developed (2) a chemical method of forming a protective film within the can, by heat treatment in an alkaline, oxidizing, phosphate medium.

The present paper reports tests of each of these methods which have been carried out at this laboratory. Tests of the presence or absence of black staining were necessarily visual and qualitative, but the accompanying plates illustrate the results obtained. Determinations of the tin content of the products were also carried out.

It has been claimed (1) that the chemically produced film protects the exterior of the can from rusting. Weathering tests were performed to investigate the efficacy of this protective film against atmospheric corrosion and, in particular, to see whether it would afford protection comparable to that given by the film of air-drying lacquer which is customarily applied to export cans.

2. Experimental.

(i) *Application of Sulphur-resisting Lacquers.*

In conjunction with the tests of sulphur-resisting lacquers, a comparison was made between three different methods of lacquer application.

(*a*) *Spray-lacquering.*—The can bodies were spray-lacquered by hand according to a method previously described (12).

(*b*) *Flush-lacquering.*—The made-up cans, approximately one-third full of lacquer, were inverted by hand and the lacquer poured with a rotary movement into the next can. By the use of a suitable thinned lacquer, at a greater dilution than for spraying, a film completely uniform over the whole internal surface of the can was obtained.

(*c*) *Roller-coating.*—The test cans were made up from plate lacquered in a commercial varnishing machine.

The cans lacquered by flush lacquering and electrodeposition (see below) were stoved with one end on, and it was necessary to ascertain whether the efficiency of the rubber sealing compound was affected by

holding at temperatures (350°-380°F.) considerably higher than the suggested maximum (290°F.) above which depolymerization occurs. However, tests of cans lacquered by these two methods, under water with 40 lb. per square inch internal pressure, failed to reveal any leaks. It may therefore be assumed that heat treatment at the usual lacquer-stoving temperatures does not adversely affect the efficiency of the rubber sealing compound.

(ii) *Application of Electrolytic Oxide Film.*

A suitable laboratory apparatus, based on the patent specifications (4, 5), was devised for applying the various electrolytic treatments to the internal surfaces of individual cans. The can to be treated formed one electrode. The other electrode was a can of smaller diameter adjusted within the can to be treated, to give an all-over clearance of approximately 3/16 in. A wide rubber band, stretched around the top of the can to be treated, allowed the electrolyte to be filled over the brim and thus ensured treatment of the entire internal surface. The two electrodes were connected through a double-pole-double-throw switch and a resistance to a 45-volt, 6-amp. battery charger operating from the 240 volt A.C. mains supply.

(*a*) *Ammonia Electrolyte.*—The electrolyte was dilute ammonia solution (1 per cent. NH_3 by weight) and the process was as follows:—

1. With the can as anode, 4 amp. were passed for 2 secs.
2. With the can as cathode, 4 amp. were passed for 2 secs.
3. With the can as anode, 0.5 amp. was passed for 4 secs.

The first two stages constituted an electrolytic cleaning process which removed residual oxide films formed by atmospheric oxidation and gave greater uniformity in the film deposited in the third stage. The values for the current passed refer to a 4-oz. can of approximately 14 square inch surface area and therefore represent current densities of 40 amp. per square foot and 5 amp. per square foot respectively (6).

(*b*) *Sodium Aluminate Electrolyte.*—In this case, the electrolyte was neutral 1 per cent. sodium aluminate solution containing 0.5 per cent. gelatin, and with a 4-oz. can as anode, 0.5 amp. was passed for 10 sec. (current density, 5 amp. per square foot) (7).

(*c*) *Electrodeposition of Lacquer Film.*—A lacquer was prepared by a local manufacturer to have the approximate composition (5, 7):—

Tung stand oil (or linseed stand oil) ..	175 parts.
Resins	100 parts.
Mn/Co drier (10:1) as linoleate	1 part.

Dilute 5 parts of lacquer with 1 part of a thinner consisting of 15 per cent. (by weight) turpentine and 85 per cent. white spirit.

This formulation gave an extremely viscous lacquer which however emulsified readily in neutral 1 per cent. sodium aluminate solution containing 1.6 per cent. rosin soap. An emulsion of 80 g. of lacquer in 100 ml. of this medium, passed twice through a hand homogenizer, was used as the electrolyte and with a 4-oz. can as anode, one amp. was passed for six sec. (current density, 10 amp. square foot). After deposition of the lacquer film, the cans were washed in a strong spray of water and stoved in the usual way.

(iii) *Chemically Produced Protective Film.*

This process is covered by British patent applications but it can be applied by interested parties without royalty or fee (2). In the present work, the can bodies and the ends without sealing compound were treated separately before making up, by immersion for five minutes at 85°-90°C. in a bath having the composition:—

Trisodium phosphate (cryst.) ..	40 g. per litre.
Sodium hexametaphosphate ..	20 g. per litre.
Potassium chromate	16 g. per litre.
Sodium hydroxide	10 g. per litre.
Perminal K.B. (wetting agent) ..	5 ml. per litre.
pH of bath	12.5

After removal from the bath, the cans were thoroughly rinsed and air-dried.

(iv) *Test Products.*

The various foodstuffs were prepared and packed according to current commercial practice. Some details of the packs and sterilization procedures are given in Table 1. All the cans were vacuum-sealed and entered the retort at air temperature, except in the case of sweet corn which had an initial temperature of approximately 170°F. The cream was held in the retort for a period considerably longer than is actually required for sterilization, because it was desired to produce immediate staining in the plain cans.

TABLE 1.

Product.	Additional Ingredients per 1-lb. Can.	Sterilization Time. Minutes.	Sterilization Temperature. °F.
(i) *Meat Products.*			
Corned brisket beef ..	..	210	228
Beef sausages	28 g. beef dripping ..	20 60 20	180 228 240
Pork sausages	28 g. lard	As for beef	As for beef
(ii) *Fish Products.*			
Tuna	56 g. cottonseed oil, 4·25 g. salt	75	240
Crayfish	7 g. salt	40	240
Australian salmon ..	7 g. salt	90	240
(iii) *Vegetable Products.*			
Green peas (var. Greenfeast)	Sweet brine (1 per cent. salt, 2 per cent. sugar)	40	240
Asparagus (green).. ..	2 per cent. brine	25	240
Onions (white)	2 per cent. brine	25	240
Sweet corn	Sweet brine (2 per cent. salt, 5 per cent. sugar)	60	250
(iv) *Dairy Products.*			
Cream (fresh)	..	120	240

It was found in preliminary experiments that a batch of six cans for each treatment and with each product gave results concordant with larger batches, and accordingly batches of six cans were used throughout.

A batch of plain cans was included for each product. Two cans from each batch were examined immediately after sterilization and cooling and the other cans were stored at air temperatures and examined at various intervals up to three months.

(v) *The Determination of Tin Content.*

The tin contents of the canned products were determined by means of the method previously described (12). Each product was separated into liquids and drained solids and a composite 50 g. sample taken of these in proportion to their weights. In the case of sausages, this sampling was carried out after melting the fat.

(vi) *Weathering Tests.*

Plain cans, cans coated externally with an air-drying lacquer after cooking and washing, and cans having the chemically-applied protective film were subjected for 30 days to external atmospheric conditions involving exposure to direct summer sunlight and frequent rain.

3. Results.

Plate 1 and Plate 2, Fig. 1 illustrate the internal appearance of plain and treated cans which contained some of the test products.

Plate 2, Fig. 2 shows three test cans which were subjected to atmospheric weathering for 30 days.

In Table 2 are given the tin contents of some of the test products packed in plain and treated cans and stored for twelve weeks at air temperatures.

TABLE 2.

Product.	Tin Content in Milligrammes per Kilogramme.			
	Plain Can.	Chemically Produced Protective Film.	Electrodeposited Lacquer Film.	"Sulphur-resisting" Lacquer.
Onions	110	35	13	15
Peas	50	35	18	13
Sweet corn ..	21	12	..	3
Sausages (beef) ..	50	36	..	..
Tuna	31	25	..	..

4. Discussion.

The particular foodstuffs used for test purposes were chosen either because specific enquiries had been received for means to prevent black staining by these products or because they were known to cause severe staining in plain tin cans. No fruit products were included since these do not normally cause black staining and because the protective films are known to break down under the action of fruit acids (2).

Certain general observations may be made regarding the occurrence of black staining in the experimental packs.

(*a*) The approximate order of decreasing intensity of staining by the test products in plain cans was as follows:—onions, peas, asparagus, tuna, crayfish, salmon, beef sausages, pork sausages, corned beef, sweet

corn, and cream. This order is also approximately that of the amounts of dissolved tin in the products packed in plain cans as shown in Table 2.

(*b*) Most of the staining occurred during the sterilization process. The increase in the intensity and extent of staining during storage was generally slight.

(*c*) The area of the can in contact with the headspace gases remained bright in cans opened immediately after sterilization. Evidently, the production of gaseous hydrogen sulphide is not a stage in the formation of sulphide stains. If the can was inverted the head-space area gradually blackened during storage under the action of sulphide ions in the liquid.

(*d*) It was observed that in the solid packs, e.g. meat packs, staining occurred chiefly where the product touched the can. This is illustrated in Plate 2, Fig. 1, where the outline of a sausage is clearly discernible in the plain can. In liquid packs the staining was usually quite general over the surface of the can, and was associated with characteristic "feathering" (Plate 2, Fig. 1); but those portions of the can in contact with the product were usually more intensely stained. Thus, pea cans showed a series of small circular blotches, onion cans larger oval blotches and asparagus cans vertical stripes. It was noticed that certain sulphur-resisting lacquers prevented the appearance of general black staining but showed the localized stains of a shape characteristic of the product. These observations illustrate the obvious fact that the concentration of staining sulphide ions is greatest at the points of greatest protein concentration.

The degrees of protection against black staining and corrosion achieved by the various methods were determined by visual examination of the cans and by estimation of the tin content of some of the products.

(i) *Lacquers.*

Nine "sulphur-resisting" lacquers, five gold-stoving lacquers, and one white enamel, all manufactured locally, and two imported "sulphur-resisting" lacquers were tested with corned beef, sausages, peas, onions, and asparagus. No illustrations are given since it was difficult to detect differences in the extent and intensity of staining in photographs because of the semi-opacity and colour of the lacquer films. However, the results of visual examination of the test cans may be summarized thus:—

(*a*) The gold-stoving lacquers were superior in appearance to the "sulphur-resisting" lacquers which were rendered semi-opaque by the added zinc compound. But the former lacquers were all permeable to sulphide ions and staining occurred beneath the film.

(*b*) In general, the best o" the local "sulphur-resisting" lacquers gave protection comparable to that given by imported lacquers. They were completely resistant to staining by meat products, but with vegetable products localized stains of characteristic shape were visible as noted above.

(c) No difference was detectable between the amount of staining present in cans lacquered by the three different methods. Since the problem was not one of extensive corrosion, as in fruit juices (12), roller coating gave satisfactory results, although the lacquer film was scratched during fabrication of the cans.

(d) Two coats of the "sulphur-resisting" lacquers were necessary to obtain satisfactory protection. Staining generally occurred beneath a single coat of the lacquers tested.

(e) The white enamel gave a lacquered can of pleasing appearance free from black staining. The enamel evidently exerted simply a masking action, since the underlying plate was stained when the lacquer was stripped off.

(ii) *Electrolytic Treatments.*

(a) *Anodic Oxide Film in Ammonia Electrolyte.*—Cans treated according to this method were tested with fish products only, and the results are shown in Plate 1. Some staining occurred with each of the varieties of fish and particularly with tuna; but the appearance of the treated cans was superior to that of the corresponding plain cans.

(b) *Anodic Oxide Film in Sodium Aluminate Electrolyte.*—This treatment was also tested only with fish products and gave rather better results than the previous treatment (see Plate 1).

(c) *Electrodeposited Lacquer Film.*—This treatment was tested with sausages, onions and peas. The test cans were not photographed but the tin contents of some of the products are shown in Table 2. The low values for dissolved tin were accompanied by freedom from black staining, indicating that a single coat of lacquer applied by this method simultaneously with an oxide film gave excellent protection against both staining and corrosion. Two coats of the same lacquer, suitably thinned, and applied by spraying gave no protection, since extensive staining occurred beneath the film.

(iii) *Chemically Produced Protective Film.*

The treated cans which contained fish products are shown in Plate 1, and those which contained sausages, peas, or onions are shown in Plate 2, Fig. 1. The method was also tested with corned beef, asparagus, sweet corn, and cream and gave complete protection against the black staining action of all the test products except tuna and onions. In Plate 1, slight staining is visible in the treated tuna can, and in Plate 2, Fig. 1, the treated onion can shows a general darkening; but, in each case, the staining is much less intense than in the corresponding plain cans.

The amounts of dissolved tin in some of the test products are given in Table 2, and, in general, the values are considerably lower than those for plain cans but are somewhat higher than those for lacquered cans. The chemically produced film therefore protects the tinplate not only against staining but also, to some extent, against corrosion.

A test was also carried out in which a batch of cans which had received the protective film were given one sprayed coat of a gold-stoving lacquer. Besides being superior in appearance to the semi-opaque " sulphur-resisting " lacquers, this treatment was more resistant to staining, particularly under the action of vegetable products.

It was considered to be of importance to test the resistance of the protective film to abrasion, and it was found that treated cans, rubbed internally with a linen cloth, stained as badly as plain cans.

(iv) *Weathering Tests.*

Plate 2, Fig. 2 illustrates the results of exposing the test cans to external atmospheric conditions for 30 days. The chemically treated can shows less corrosion than the plain can but more corrosion than the lacquered can. Corrosion commenced at points around the end seams where the protective film had been fractured during seaming. It will be observed that the lacquered can shows some corrosion at the top seam, evidently at points where the action of the seaming head exposed the steel base plate. While the plain can is corroded over the whole surface, the chemically treated can is corroded only on certain areas which are probably those where the protective film has been damaged by abrasion during handling. Because of the sensitivity of the protective film to abrasion, it cannot be regarded as a possible substitute for the external lacquering of export cans.

It is necessary to consider the applicability of the above treatments to the commercial manufacture of food cans in this country. The " sulphur-resisting " lacquers in current use are chiefly imported, but the present work shows that lacquers of comparable resistance to black staining are manufactured locally.

The electrolytic methods of applying protective films and lacquer films are not considered to be commercially important at the present time because of the expensive plant which would be required to treat cans at the usual rates of production.

The chemical process for the formation of protective films seems to be capable of immediate commercial application. The economics of the large scale production of treated cans have not been investigated, but the costs of the treatment should add little to the total costs. The consumption of chemicals in the bath is small, the chief losses being drag-out loss, which is made up by adding back liquid from the first rinsing bath, and loss of alkalinity by absorption of atmospheric carbon dioxide, which is made up by adding caustic soda. The plant required is an enamelled iron tank provided with heating coils and two rinsing tanks. It is claimed (2) that the process can be successfully applied to tinplate sheet, but the effects of abrasion noted above indicate that it would be necessary to handle the plate, during fabrication of the cans, at least as carefully as lacquered plate. The process would probably give better results if applied to the can bodies as they leave the body-forming machine, and to the ends after stamping.

It may be noted that food canners prefer lacquered cans for higher-priced packs because of the pleasing golden appearance of the lacquer and, in this connection, cans chemically treated and then coated with a gold-stoving lacquer are superior in appearance to cans coated with a semi-opaque " sulphur-resisting " lacquer.

5. Acknowledgments

The authors are indebted to Mr. P. R. Maguire for preparing Plates 1 and 2, and to the following organizations for their co-operation:— Messrs. Lewis Berger and Sons Pty. Ltd., Messrs. W. Angliss and Co. (Aust.) Pty. Ltd., Messrs. Richard Hughes Pty. Ltd., Messrs. Irwin and Sheehan Pty. Ltd., and Messrs. H. Jones and Co. Pty. Ltd.

6. References.

1. Anon. (1939).—Protection of Tinplate from Corrosion. International Tin Res. Development Coun., Fourth Gen. Rept. Publication No. 95, p. 13.
2. Anon. (1940).—Protective Films on Tinplate. *Tin and its Uses.* No. 5 : 7, and No. 7 : 9.
3. Bohart, G. S. (1929).—Process and Product for Preventing Discolouration of Canned Foods. U.S. Patent No. 1, 699, 274.
4. Clayton, W. (1937).—Internal Lacquering of Cans. *Food Manuf.* **12** : 119.
5. Crosse and Blackwell Ltd. *et al.* (1936).— Process and Apparatus for the Internal Coating of Metal Containers. Brit. Patent No. 455, 810.
6. Crosse and Blackwell Ltd. and Sumner, C. G. (1938).—An Improved Process for Treating Tinplate and Tinplate Articles. Brit. Patent No. 479, 681.
7. Crosse and Blackwell Ltd. *et al.* (1938).—Improved Process of Protecting Metal Surfaces by Electrodeposition. Brit. Patent No. 492, 900.
8. Dill, D. B. and Clark, P. B. (1926).—Can Corrosion and Blackening in Certain Marine Products. *Ind. Eng. Chem.* **18** : 560.
9. Fitzgerald, F. F., Bohart, G. S., and Kohman, E. F. (1922).—Black Discolouration in Canned Corn. Nat. Canners Assoc., Bull. 18L, 27 pp.
10. Harrison, F. C., and Hood, E. G. (1923).—Discolouration, Smut, or Blackening of Canned Lobsters. Canada, Coun. Sci. Ind. Res. Rept. No. 12.
11. Jackson, C. J., Howat, G. R., and Hoar, T. P. (1936 and 1937).—Discolouration and Corrosion in Canned Cream. *J. Dairy Research* **7** : 284, and **8** : 324.
12. Lynch, L. J., and Kefford, J. F. (1939).—The Internal Lacquering of Tinplate Containers for Foods. I. The Determination of Tin in Foods and a Survey of the Tin Content of Some Canned Foods. *J. Coun. Sci. Ind. Res.* (Aust.) **12** : 303.
13. Macphail, A. (1897).—Discolouration in Canned Lobsters. Canada, 29th Ann. Rept. Dept. of Marine and Fisheries. Fisheries Branch, Supplement No. 2. Quoted in full by Bitting, A. W. Appertizing. Pp. 852 + v. (San Francisco, The Trade Pressroom, 1937).
14. Rupp, V. R. (1935).—Canned Meats. Effect of pH on the Formation of Ferrous Sulphide. *Ind. Eng. Chem.* **27** : 1053.
15. Sumner, C. G. (1940).—The Anodic Deposition of Oleo-resinous Lacquers. *Trans. Faraday Soc.* **26** : 272.

Studies on the Prevention of Shrinkage in Woollen Goods.

By M. R. Freney, B.Sc. and M. Lipson, B.Sc.**

Summary.

Laboratory studies on the action of alcoholic solutions of alkalies on wool are described, particularly with regard to the unshrinkability which results from such treatment.

The optimum conditions for the treatment have been determined by systematic studies, both for the continuous process, in which wool is treated for 2 minutes or less, and for the steeping process. The continuous process was used in the industrial trials outlined in this paper. It is not claimed that the machine described is entirely satisfactory, and further work on the chemical engineering aspects of the process is being continued. The amount of chemicals consumed in treating wool in this machine has been determined, and costs of chemicals for treatment of the wool have been estimated. The steeping process has also been applied on a semi-industrial scale. The permissible limits of variation of the factors influencing the continuous process and the steeping process are tabulated.

No alteration in weight of wool results from treatment, and the regain of treated wool has been found to be the same as that of normal wool. Unless restored by surface active agents, the handle is impaired by the treatment. Among such softening agents, the cationic soaps give the best results.

Washing and wearing tests on several types of socks indicated that the treatment prolonged the useful life of the garments.

1. Introduction.

The ultimate criterion for any unshrinkable process is whether it can prolong the useful life of a garment. It is implied that any process by which wool is treated to reduce its felting properties should not so affect the wool that (*a*) its resistance to wear is diminished, (*b*) articles made from it lose their original shape, or (*c*) its appearance becomes unattractive, for garments thus affected would need to be discarded at an early stage, even though the wool were unshrinkable. Complete unshrinkability is undesirable, since a moderate amount of felting minimizes the disability noted under (*b*). Thus the best test for determining the true worth of any unshrinkable process is to have numbers of identical garments—some treated, some untreated—worn and washed in a normal manner.

This type of test, since it may extend over many months, is obviously unsuited for systematic studies of the influence of the variables of any process on its performance. Some type of accelerated test had, therefore, to be devised which would enable quick qualitative and quantitative assessment of unshrinkability. Such an accelerated test would not be designed primarily for comparisons between different processes, but rather for the evaluation of the optimum values of the variables for any one process. The tests which have been considered and used in the present work are set out in this and the following paper.

* An officer of the Council's McMaster Animal Health Laboratory, Sydney, seconded to the Division of Industrial Chemistry.

Practical wool men generally assess shrinkage by manual and visual examination of wool before and after washing. These examinations really give quick qualitative and roughly quantitative estimations, and they may be carried out on fabrics, hanks of yarn, or short lengths of sliver.

In a previous paper†, referred to hereafter as Pamphlet 94, we gave an outline of a process by which the felting properties of wool could be so reduced that it became substantially unshrinkable. The process involved treatment by alkali, and the most promising reagents were solutions of either potassium hydroxide or sodium hydroxide in ethyl alcohol, which contained a small percentage of water. A substantial reduction in the tendency to shrink and felt resulted from immersing the wool for 1 or 2 minutes in a 7 per cent. solution of potassium hydroxide in 95 per cent. alcohol. This short period of treatment permitted wool tops to be treated continuously in a backwash type of machine. Special care is needed to acidify the wool thoroughly before it comes in contact with water, as dilute solutions of alkali in water rapidly damage wool. The appearance of the wool is unaffected by the process, and yarns made of treated wool have a somewhat higher breaking strength and are more extensible than similar yarns of normal wool.

The liquors used in the process do not give off noxious fumes, and are not highly corrosive, although care must be taken to limit the fire hazard. Simple machinery can, therefore, be used to treat wool commercially.

Results of wearing and washing tests on garments made of wool treated by the process, described in Pamphlet 94, indicated possible commercial application of the process and justified a continuation of the investigations. In the present paper further laboratory tests are described and descriptions and results of various industrial trials are given. The amounts of chemicals used in treatment and the manufacturing properties of the treated wool are also set out.

2. Laboratory Studies.

A. *Assessment of Unshrinkability.*

The method which has been used in the present work consists of measuring the area of relaxed rectangular strips of fabric before and after washing. For accurate results a planimeter is necessary.

Another method was to measure the change in extensibility of the fabric before and after washing. Our colleague, Mr. E. H. Mercer, has devised an apparatus whereby this may be done, and the results obtained, which are described in the succeeding paper, are roughly parallel to those obtained by the area measurements with the planimeter.

These laboratory methods give quantitative figures indicating the degree of unshrinkability under specified conditions.

In our experiments, a small commercial washing machine manufactured by the Savage Arms Corporation of Utica, New York, United States of America, was used. This machine rotates the garments in the wash liquor and dries by centrifuge. The liquor used consisted of

† Freney, M. R., and Lipson, M. (1940).—Coun. Sci. Ind. Res. (Aust.), Pamph. No. 94.

0.3 per cent. sodium oleate solution, containing 0.05 per cent. of sodium sesquicarbonate. The initial temperature of the liquor was 55°C., falling to 44°C. during one hour's washing.

B. *Shrinkage of Different Types of Fabric.*

One of the factors affecting shrinkage of a fabric is the knit. The effect of different types of yarn and of knitting conditions on shrinkage was studied, using a range of tubular fabrics knitted on a Scott and Williams machine of 82 needles. The results are set out in Table 1, and indicate the need for using only one type of fabric in systematic studies. We have selected standard lengths of loosely knitted fabric made from three-ply yarn, each ply of 18's count, from 60's Merino wool, for the work described below.

C. *Optimum Conditions of Treatment.*

Unshrinkability achieved by using solutions of potassium hydroxide in alcohol depends mainly upon time of treatment, strength of the potassium hydroxide, percentage of water in the reagent, and temperature.

It is important to know over what range each of these critical factors can be varied without affecting markedly the degree of unshrinkability attained. A large number of experiments were therefore carried out in which one factor only was varied, whilst the other three were kept constant.

For these experiments, strips of machine-knitted, tubular fabric, 15 in. x 3½ in., and weighing 20 grammes, were obtained and, after relaxation, an area 10 in. long by 3½ in. wide was marked out on them. The wool before treatment had a moisture content of 14 per cent. The reagents were prepared from potassium hydroxide (Merck) and ethyl alcohol (C.P.), and 250 ml. of liquor were used for treating each piece of fabric. One per cent. by volume of glycerol was added to each treatment solution to prevent discolouration. After treatment the fabrics were squeezed in a mangle and neutralized in one litre of 5 per cent. by volume aqueous sulphuric acid.

Each series of treated fabrics and an untreated sample were washed at the same time in the "Savage" washing machine, using the conditions specified in section 2A.

The experiments were divided into two main groups. In the first, short immersion periods which could be applied industrially to a *continuous* process were studied. In the second group, a longer immersion period was employed to determine the best conditions for a *steeping* process. The results of these experiments, which are discussed below, are shown in Tables 2 and 3. Tables 4 and 5 show the permissible limits of variation of the factors influencing the continuous process and the steeping process respectively.

(i) *Experiments in which conditions for continuous treatment were varied.*

(*a*) *Time.*—With the concentration of potassium hydroxide at 7 per cent., water at 5 per cent., and a temperature of 25°C., satisfactory unshrinkability was achieved when the time of immersion varied between 1½ and 2½ minutes.

TABLE 1.—SHRINKAGE OF DIFFERENT TYPES OF FABRICS.

Type of Fabric.	Number of Half-hour Wash Periods.	Percentage Shrinkage.
Loose one-ply	1	70
Tight one-ply	1	43
Loose two-ply	4	72
Tight two-ply	4	62
Loose three-ply	4	57
Tight three-ply	4	17
Loose four-ply	4	38

TABLE 2.—AREA SHRINKAGE OF WASHED FABRICS.

(Short Treatment.)

Series.	Strength of KOH.	Time.	Water Content.	Temperature.	Shrinkage.	
					After Half Hour's Wash.	After One Hour's Wash.
	Per cent.	Seconds.	Per cent.	°C.	Per cent.	Per cent.
A. Time variable ..	7·0	90	5·0	25	14	17
	7·0	120	5·0	25	12	15
	7·0	150	5·0	25	6	14
Untreated	..	..	..	..	25	31
B. Strength of KOH variable	4·0	120	5·0	25	10	14
	5·0	120	5·0	25	8	13
	5·5	120	5·0	25	7	12
	6·0	120	5·0	25	6	9
	6·5	120	5·0	25	7	11
	7·0	120	5·0	25	9	15
Untreated	..	..	..	..	22	39
C. Water content variable	7·0	120	2·0	25	12	13
	7·0	120	3·0	25	11	15
	7·0	120	4·0	25	7	15
	7·0	120	4·5	25	8	11
	7·0	120	5·0	25	12	14
	7·0	120	5·5	25	7	15
	7·0	120	6·0	25	5	12
Untreated	..	..	..	..	19	30
D. Temperature variable	7·0	120	5·0	15	13	17
	7·0	120	5·0	20	7	18
	7·0	120	5·0	25	7	14
	7·0	120	5·0	30	9	13
	7·0	120	5·0	35	5	9
Untreated	..	..	..	..	14	30

TABLE 3.—AREA SHRINKAGE OF WASHED FABRICS.
(Steeping Treatment.)

Series.	Strength of KOH. Per cent.	Time. Minutes.	Water Content. Per cent.	Temperature. °C.	Shrinkage. After Half Hour's Wash. Per cent.	Shrinkage. After One Hour's Wash. Per cent.
A. Strength of KOH variable	0·25	30	3·0	25	23	31
	0·50	30	3·0	25	14	27
	0·75	30	3·0	25	13	20
	1·00	30	3·0	25	14	25
	1·25	30	3·0	25	13	23
Untreated	..	..	..	..	34	48
B. Water content variable	0·75	30	0	25	11	17
	0·75	30	1·0	25	12	18
	0·75	30	2·0	25	11	18
	0·75	30	3·0	25	11	23
	0·75	30	4·0	25	13	23
	0·75	30	5·0	25	13	24
	0·75	30	6·0	25	15	23
	0·75	30	7·0	25	17	28
Untreated	..	..	..	..	23	42
C. Water content variable	0·75	30	0	25	10	18
	0·75	30	1·0	25	14	21
	0·75	30	2·0	25	6	21
	0·75	30	3·0	25	11	21
	0·75	30	4·0	25	16	22
	0·75	30	5·0	25	12	20
	0·75	30	6·0	25	15	24
	0·75	30	7·0	25	16	23
Untreated	..	..	..	..	32	45
D. Temperature variable	0·75	30	5·0	15	13	19
	0·75	30	5·0	20	12	18
	0·75	30	5·0	25	13	19
	0·75	30	5·0	30	10	15
	0·75	30	5·0	35	15	19
Untreated	..	..	..	..	23	38

TABLE 4.—TOLERANCES FOR VARIABLES IN THE CONTINUOUS TREATMENT.*

Variable.	Lower Limit.	Upper Limit.	Effect of Exceeding Upper Limit.
Strength of KOH	4 per cent. ..	7 per cent.	
Time of treatment	$1\frac{1}{4}$ minutes ..	$2\frac{1}{2}$ minutes ..	Damage to wool
Temperature of treatment ..	23° C. ..	28° C. ..	Handle inferior
Water content of reagent ..	2 per cent. ..	6 per cent. ..	Handle inferior

* Based on results of both laboratory and semi-industrial experiments.

TABLE 5.—TOLERANCES FOR VARIABLES IN THE STEEPING TREATMENT.*

Variable.	Lower Limit.	Upper Limit.	Effect of Exceeding Upper Limit.
Strength of KOH	0·5 per cent. ..	1·25 per cent.	Damage to wool
Temperature of treatment ..	15° C. ..	25° C. ..	Damage to wool
Water content of reagent ..	Nil	7 per cent.	

* Based on results of laboratory experiments with time of immersion 30 minutes.

(*b*) *Strength of potassium hydroxide.*—With the concentration of water at 5 per cent., a temperature of 25°C., and immersion period of 2 minutes, satisfactory results were achieved with KOH concentrations between 4 and 7 per cent.

(*c*) *Water content.*—With the potassium hydroxide content at 7 per cent., a temperature of 25°C., and an immersion period of 2 minutes, satisfactory results were obtained with water contents between 2 and 6 per cent.

(*d*) *Temperature.*—With the potassium hydroxide content at 7 per cent., the water content at 5 per cent., and the time at 2 minutes, the best shrinkage reduction resulted from treatment at 25° to 35°C. At 30° to 35°C., however, the handle was inferior (to that at 25°C.), and it was found subsequently that there was considerable combination of alkali with the wool (at 30° to 35°C.). Thus, in industrial practice, a treatment temperature of 25°C. would be most satisfactory.

The results obtained in these studies show that the optimum conditions for the continuous treatment are 6 to 7 per cent. KOH and 5 per cent. water at 25°C. for 90 seconds. The most critical feature is temperature. Satisfactory shrinkage reduction is obtained if the KOH content drops as low as 4 per cent. or the water varies between 2 and 6 per cent. These conclusions are included in Table 4.

(ii) *Experiments in which conditions for the steeping process were varied.*

(*a*) *Time.*—In studying the factors for the steeping process, we have used a 30-minute period throughout, as control of the time period is easier in long than in short treatments.

(*b*) *Strength of potassium hydroxide.*—When the water content was kept at 5 per cent. and temperature at 25°C., satisfactory unshrinkability was found to result from treatment with 0.5 to 1.25 per cent. potassium hydroxide.

(*c*) *Water content.*—With a potassium hydroxide content of 0.75 per cent. and a temperature of 25°C., satisfactory unshrinkability resulted with dry reagents or with water contents up to 7 per cent. It has been shown previously that water must be present to produce satisfactory unshrinkability. When dry reagents were used, the moisture contained in the wool evidently sufficed for this purpose.

(*d*) *Temperature.*—With 0.75 per cent. of potassium hydroxide and 5 per cent. water in the reagent, the temperature could be varied from 15°C. to 35°C., and satisfactory unshrinkability resulted in all cases. At the higher temperature, however, some damage to the wool was noted. It is apparent that temperature, so critical a factor in the continuous treatment, is of less importance with longer treatments.

These tests indicate that, in an industrial steeping process, using a 30 minutes' immersion period, a convenient reagent to use would be 0.75 per cent. potassium hydroxide in ethyl alcohol containing 5 per cent. of water, and that temperatures from 15°C. to 25°C. are satisfactory. At temperatures above 25°C., however, some damage to the wool was noted. These conclusions are summarized in Table 5.

D. *The Amount of Alkali removed by the Wool in the Continuous Process.*

General chemical principles indicate that, if alkali combined with wool during treatment, the amount up to a saturation value would depend upon the time of immersion of the wool in the alkali and the temperature of the alcoholic bath. Experiments have therefore been carried out to determine how much alkali is consumed in treating definite amounts of wool. It was desirable in this work to simulate the conditions that would be used industrially where a large amount of wool sliver would be treated in a comparatively small volume of liquor. The apparatus devised for this purpose consisted of a large U-tube, 2 feet high, made from ¾-in. glass tubing fitted at one end with a filter funnel, the whole apparatus being immersed in a water bath. The wool (50 g.), in the form of a thin sliver, was led into the U-tube which contained the treatment liquor (200 ml.). It was pulled through the U-tube by a set of horizontal rollers placed above the funnel at the exit end. This arrangement allowed the liquor squeezed from the wool to run down the sliver emerging from the funnel, which also collected any drips. The rollers were adjusted so that each gramme of wool removed approximately 1 ml. of liquor, which was similar to the conditions attained in a pilot plant, where 10 lb. of wool removed 1 gallon of liquor.

Time of immersion of the wool in the liquor was varied by adjusting the speed of the rollers, and temperature was controlled by means of the water bath. The strength of the potassium hydroxide was determined by titration before and after each treatment. The results of the experiments are set out in Table 6 and shown graphically in Fig. 1. An approximate estimate of the amount of alkali actually combining with the wool can be obtained from the table.

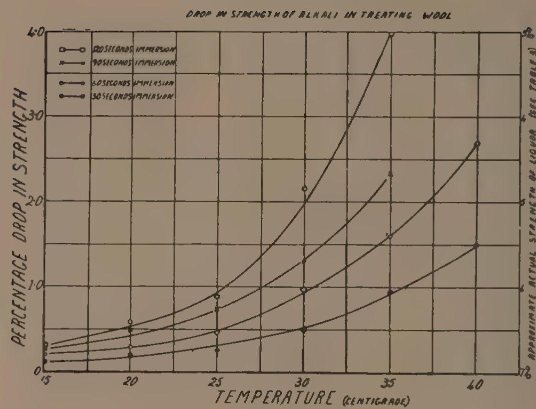


FIG. 1.

TABLE 6.—DROP IN STRENGTH OF ALKALI DURING TREATMENT.

Time.	Temperature. °C.	Strength of KOH Before. Per cent.	Strength of KOH After. Per cent.	Drop in Strength. Per cent.
30 seconds ..	15	6·70	6·57	0·13*
	20	6·85	6·65	0·20*
	25	6·70	6·48	0·22
	30	6·73	6·20	0·53
	35	6·73	5·77	0·96
	40	6·73	5·23	1·50
1 minute ..	15	6·73	6·57	0·16
	20	6·68	6·40	0·28
	25	6·68	6·21	0·47
	30	6·68	5·69	0·99
	35	6.68	5·07	1·61
	40	6·77	4·08	2·69
90 seconds ..	15	6·71	6·49	0·22
	20	6·77	6·29	0·48
	25	6·77	6·03	0·74
	30	6·77	5·45	1·32
	35	6·95	4·61	2·34
	40	Wool deteriorated during treatment		
2 minutes ..	15	6·71	6·46	0·25
	20	6·71	6·17	0·54
	25	6·71	5·81	0·90
	30	6·71	4·57	2·14
	35	6·95	2·84	4·11
	40	Wool deteriorated during treatment		

* In all experiments 50 g. of wool were treated, except in these, where the weights were 47 g. and 55 g. respectively.

These studies indicate that the drop in strength of the alkaline liquor, which is slight at 15°C., becomes greater as the temperature rises, but is still inconsiderable at 25°C. For simplicity in industrial treatment, it is considered best to use a temperature of 25°C., but if the temperature should rise as high as 28°C. in summer, a satisfactory result is still obtainable.

E. *Use of Sodium Hydroxide in place of Potassium Hydroxide.*

It was indicated in Pamphlet 94 that, for the quick treatment, potassium hydroxide gave better results than sodium hydroxide. This difference, however, is less apparent when longer periods of treatment are used. Short treatments and steeping treatments were carried out with sodium hydroxide, using the same conditions as were found optimum for potassium hydroxide. The maximum solubility of sodium hydroxide in 95 per cent. alcohol at 25°C. is only 5.8 per cent., and a 5.0 per cent. solution was used, therefore, for tests of the short treatment. The results of washing tests shown in Table 7 indicate that sodium hydroxide solutions are satisfactory in the laboratory for the steeping process, but for the continuous process the results are less satisfactory than when potassium hydroxide is used.

TABLE 7.—AREA SHRINKAGE OF WASHED FABRICS.*

Strength of NaOH. Per cent.	Time.	Water Content. Per cent.	Temperature. °C.	Percentage Shrinkage.	
				After Half Hour's Wash.	After One Hour's Wash.
0·75	30 minutes ..	5·0	25	16	26
1·00	30 minutes ..	5·0	25	13	20
1·25	30 minutes ..	5·0	25	14	17
5·0	60 seconds ..	5·0	25	24	33
5·0	90 seconds ..	5·0	25	16	27
5·0	120 seconds ..	5·0	25	14	25
Untreated ..	..	..	..	35	48

* See Tables 2 and 3 for comparison with KOH.

F. *Weight of Wool before and after Treatment.*

Any alteration in the weight of wool as a result of the treatment was less than 0.1 per cent.

G. *Regain of Treated Wool.*

Samples were treated with 7 per cent. potassium hydroxide in 95 per cent. ethyl alcohol at 20°C. for 1 minute, 2 minutes, and 3 minutes 10 seconds respectively. When conditioned after treatment at 78 per cent. relative humidity and 22°C., these samples had "regains" of 15.6, 15.5, and 15.4 per cent. respectively. Normal wool, under the same conditions, had a "regain" of 15.9 per cent.

Table 8 shows that for another series of treatments, the "regain" was equal to that of normal wool.

Table 8.—Regain of Treated Wool.

Sample.	Regain at 24·5 °C. and 74 per cent. Relative Humidity.	Regain at 27 °C. and 61 per cent Relative Humidity.
Treated* 30 seconds	11·1	8·5
,, 60 ,, ...	11·0	8·5
,, 90 ,, ...	11·1	8·7
,, 120 ,, ...	11·1	8·8
,, 150 ,, ...	11·1	8·5
Untreated	11·1	8·5

* Treatment liquor 7 per cent. potassium hydroxide in 95 per cent. alcohol at 25° C.

H. *Softening of Treated Wool.*

All known commercial treatments for rendering wool unshrinkable, if not followed by suitable corrective treatment, cause the handle of the product to be inferior. Treatment with surface active reagents (approximately 0.2 per cent. solution), such as the sulphated fatty alcohols and cationic soaps, improves the handle very considerably. Samples treated by such methods have been adjudged satisfactory by competent authorities.

I. *Time in Acid.*

The acid bath must ensure that the alkali in the wool is effectively neutralized before the latter comes in contact with water. In 5 per cent. by volume sulphuric acid in water, a period of 30 seconds is ample for tops. In more dilute acid, if the wool is squeezed while immersed, a similar period would be satisfactory. Longer immersion in the acid does not harm the wool, but is unnecessary.

3. Industrial Trials.

Laboratory studies have indicated that in applying the process to industry, any convenient period of treatment can be selected, and suitable concentrations of the reagent determined. Using a treatment period of under 2 minutes, the wool can be treated in the form of tops, and adequate control of the various factors may be expected in a machine of the backwash type. For piece goods, a longer period of immersion, using weaker solutions, may be more convenient.

Both types of treatment have been tried on a semi-industrial scale, but the tests of the continuous only have been under the control of the Council. The steeping process was applied on a semi-industrial scale to treat dyed socks at the mill of Messrs. Holeproof Limited, Melbourne. The discussion below deals solely with the continuous treatment of tops at the mill of Messrs. John Vicars and Co. Pty. Ltd., Sydney.

A. *Wool to be Treated.*

Earlier work has shown that the regain is a critical factor only when it is very low—below 5 per cent. Since tops usually contain approximately 15 per cent. of moisture, it is unnecessary to condition the wool before treatment. The tops to be treated should be dry-combed, and contain as little soap and oil as possible.

B. *Description of Machinery.*

In Pamphlet 94, a three-bowl machine was described for the continuous treatment of the wool in sliver form. In further trials this, with several modifications, has treated wool at the rate of over 400 lb. a day. A plan of the machine at present in use is shown in Fig. 2. A longer bowl than that illustrated would be more desirable, for, in a bowl of the present size, there is the possibility of tangling. The dimensions of the second bowl are satisfactory, as less sliver accumulates in it. The wool should pass through all rollers at exactly the same speed, in order to ensure constant treatment time. Temperature, which is a critical factor for the short treatment, should be thermostatically controlled at 25° ± 2°C.

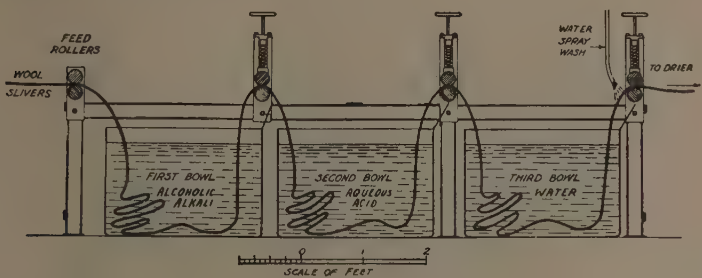


Fig. 2.

C. *Directions for Carrying out Continuous Treatment.*

Preparing the liquors.—The following are the directions for making up 30-gallon lots of the liquors:—

Liquor of the first bowl.—21 lb. of potassium hydroxide flake 90 per cent., are added with stirring to $1\frac{1}{2}$ gallons of water, cooled to 70°C. or less, and added with stirring to $28\frac{1}{2}$ gallons of methylated spirits (absolute alcohol, denatured with 2 per cent. methyl alcohol). The addition of 3 lb. of glycerine to every 30 gallons of liquor reduces the amount of discolouration which develops on standing. This is not necessary, however, if the liquor is to be used within two days of being made.

Liquor of the second bowl.—One and a half gallons of commercial sulphuric acid (98 per cent.) is added to $28\frac{1}{2}$ gallons of water, not vice versa.

Liquor of the third bowl.—The third bowl is filled with fresh water, and a steady stream of water is allowed to play on the wool as it emerges.

Control of the various factors during treatment.—In the machine described, six slivers are treated simultaneously. Fed through rollers these are allowed to remain in the first bowl for 80 seconds, and are then led through the second set of rollers into the acid bowl, the total time of contact with alkaline solution being 90 seconds. The slivers remain in the second bowl for 30 seconds and are finally passed through the third bowl and collected in trucks for drying. The solution in the

first bowl is kept to its original level by occasional additions of liquor of the original strength. Should the strength of the alkali fall to 4.5 per cent., it is advisable to add a solution of potassium hydroxide, more concentrated than that usually added. The volume of liquor in the second bowl does not alter during treatment. One gallon of concentrated sulphuric acid should be added to the second bowl after every 150 lb. of wool. Extreme care must be taken to ensure that the liquor of this bowl never becomes neutral.

D. *Manufacturing Properties of Treated Wool.*

After wool has been treated in top form, it draws and spins satisfactorily and dyes evenly. It is more reactive towards acid dyestuffs than normal wool, and when both are dyed in the same batch, the treated dyes to a darker shade.

4. Factors Influencing Cost.

A. *Chemicals.*

The cost of chemicals in treating wool per pound will depend on (*a*) the cost of the chemicals needed and, (*b*) the consumption of chemicals, which depends upon the type of machinery used.

For the continuous process, a liquor of the following approximate composition is recommended: 7 per cent. KOH in 95 per cent. ethyl alcohol; 1 per cent. of glycerine may be added, though this is not always necessary, and for costing the process this may be ignored. In the second bowl a solution of 5 per cent. by volume of sulphuric acid is used. The cost of these chemicals in ton lots in Sydney on 16th December, 1940, was—

Potassium hydroxide 90 per cent. flake ..	£72 per ton.
Sulphuric acid 98 per cent.	£10 16s. per ton.
Ethyl alcohol denatured with 2 per cent. methanol	2s. 4d. per gallon.

It can be calculated from these figures that 1 gallon of liquor of the first bowl would cost 2s. 8d., and for neutralization this would need 0.63 lb. of sulphuric acid, costing approximately ¾d. The chief item of cost is the alcohol, and every effort should be made to reduce the consumption of this. The design of the machine determines the amount of wool that can be treated in each gallon of liquor. In the machine described, 10 lb. of wool removed 1 gallon of liquid from the first bowl, and the cost of this and the sulphuric acid needed to neutralize it would be 2s. 8¾d., equal to 3.3d. per lb. of wool. Any device which lessened the amount of liquor removed from the first bowl would give a proportionate reduction in cost. A greater efficiency in squeezing would achieve this result.

By centrifuging, it has been found possible to reduce the amount of liquor retained by the wool to 2 gallons per 100 lb., the cost of which would be 0.66d. per pound of wool, but at present these low costs are confined to the steeping treatment.

In the three-bowl machine which has been described, the alcohol removed from the first bowl accumulates in the second and third bowls, and by distillation this can be recovered. Whether the alcohol is worth recovering depends on its concentration. It has been calculated for

the machine described that the percentage by volume of alcohol in the liquor of the second bowl would be 25 per cent. by volume when 90 lb. of wool had been treated, 40 per cent. for 160 lb. and 66 per cent. for 330 lb. Actual determinations of alcohol content of the liquor agree well with these calculated figures. The cost of recovering alcohol from liquor of such composition and concentration has been considered by the Colonial Sugar Refining Company, who have submitted the following report:—

"We would emphasize that approval of the Customs would first be necessary. Under existing regulations no such spirit is allowed to re-enter the Distillery. Should a concrete scheme be evolved, therefore, it is important that the Customs authorities be approached first.

As regards the likely charge which we would make for the recovery of the alcohol contained in the weak spirit, we have made some rough estimates which are as follows:—

Treating 24 per cent. alcohol (by weight) 6½d. per gallon of 94 per cent. alcohol.

Treating 35 per cent. alcohol (by weight) 5¾d. per gallon of 94 per cent. alcohol.

Treating 42 per cent. alcohol (by weight) 5½d. per gallon of 94 per cent. alcohol.

The above figures can only be considered as approximations: the working-out of reliable figures would take considerable time and probably necessitate actual plant trials.

Basing calculations on the finding that, in the machine described, 10 lb. of wool transferred 1 gallon of liquor from the first to the second bowl (both bowls containing 30 gallons of liquor), and assuming that wool would be treated on a sufficiently large scale (100,000 lb.) the following rough costs were made for the actual consumption of alcohol in treatment.

(*a*) *Recovering alcohol from 24 per cent. solution.*

Per 100 lb. wool:

Spirit lost	= 1.32 gallons @ 26d. =	34.3d.
Spirit recovered	= 8.48 gallons @ 6.5d. =	55.1d.
	Total =	89.4d.

Cost = 0.894d. per lb. of wool.

(*b*) *Recovering alcohol from 35 per cent. solution.*

Per 100 lb. wool:

Spirit lost	= 2.00 gallons @ 26d. =	52.0d.
Spirit recovered	= 7.80 gallons @ 5.75d. =	44.8d.
	Total =	96.8d.

Cost = 0.968d. per lb. of wool.

(c) Recovering alcohol from 42 per cent. solution.

Per 100 lb. wool:

Spirit lost	= 2.37 gallons @ 26d.	=	61.6d.
Spirit recovered	= 7.43 gallons @ 5.5d.	=	40.8d.
	Total	=	102.4d.

Cost = 1.024d. per lb. wool."

Assuming that such an alcohol recovery scheme is adopted, the overall cost for chemicals per lb. of wool treated by the continuous process would be about 1.5d. per lb.

B. *Capital Costs.*

The cost of constructing the machine which we have described was £120. The capacity of this machine is approximately 400 lb. of wool in 8 hours. If a longer first bowl were used, the capital cost would not be greatly increased, but the efficiency of the machine would be improved.

C. *Power and Labour Costs.*

No detailed estimate of these is possible. However, the machinery described for the continuous process can be satisfactorily operated by one man assisted by a boy.

5. Washing and Wearing Tests on Treated Socks.

As pointed out earlier in this paper, the value of any process for producing unshrinkable wool must be assessed ultimately by normal washing and wearing tests, carried out on garments made from treated wool. Experiments have, therefore, been undertaken to compare treated wool with untreated when subjected to the usual conditions of wear and washing.

Garments of several different types were tested, including machine-knitted white tennis socks, hand-knitted military and air-force socks, and the usual type of men's hose with or without "Lastex" tops. Some were treated in the laboratory either by the short or the longer (steeping) process; others were made from wool treated in sliver form on the semi-industrial scale. These socks were then paired with similar untreated socks and issued to different individuals for normal wear and laundering.

These tests are still in progress, but the results to date on 29 pairs of socks worn by 15 different individuals reveal (1) that, as far as size is concerned, the treated were still satisfactory when the untreated were considered unwearable; (2) that all the treated socks retained their original patterns and did not become fluffy whereas the untreated socks developed fluffy surfaces; (3) that the treatment had no deleterious effect on the "Lastex" tops; and (4) that the colour of the socks used was unaffected.

Hence it may be confidently stated that the useful life of socks treated by the process has been prolonged.

6. Acknowledgments.

It is with pleasure that we record our appreciation of the encouragement given to us throughout the work by Mr. D. A. Gill, Officer-in-Charge of the McMaster Laboratory. We are indebted to Dr. I. W. Wark and Mr. E. J. Drake for their help in the preparation of this paper, and for their advice and criticism since the work has been transferred to the Division of Industrial Chemistry.

For help and criticism throughout the work, we are indebted to our colleague, Mr. E. H. Mercer.

We acknowledge the help given freely by the firms of John Vicars and Company Proprietary Limited, Sydney, the Colonial Sugar Refining Company Limited, Sydney, and Holeproof Limited, Melbourne.

We wish to thank Mr. G. F. Nicholls of Holeproof Limited for keeping us informed of the development of the steeping process.

A Method for Assessing Shrinkage in Woollen Fabrics.

*By E. H. Mercer, B.Sc., A.Inst.P.**

Summary.

A method of studying the felting properties of wool by inflating tubular knitted fabrics is described. A comparison is made between untreated wool and wool treated by two "unshrinkable" processes.

1. Introduction.

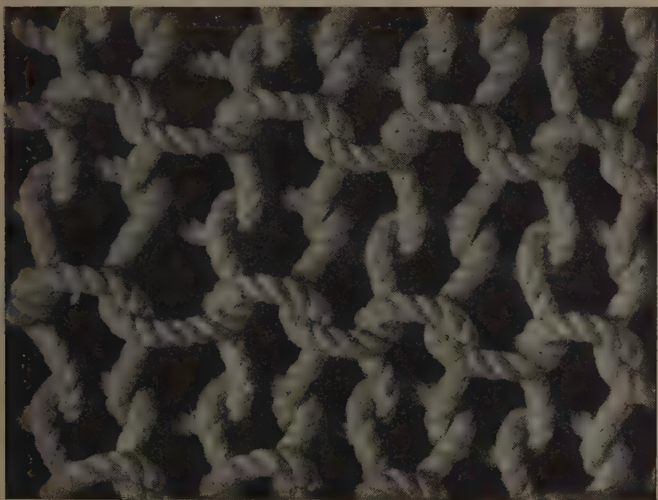
A woollen garment on shrinking becomes unwearable, firstly because it is smaller in size, and secondly because of its reduced extensibility. Shrinkage determinations are usually made in terms of the change in area alone. It is equally significant to measure the change in extensibility, and this paper describes a simple method of determining this characteristic of knitted fabrics, and its use in comparing the results of some unshrinkable processes.

In making area measurements care must be taken to distinguish between "set" size and "relaxed" size. The "relaxed" size of a fabric is that which it assumes after standing in water for some hours. This is reproducible and is suitable for measurement. By pressing and drying, the garment may be set to various sizes and shapes on account of the property possessed by animal fibres of retaining in part a change in length or shape when dried in a stressed condition. This form of set is released in water, and the "set" size is thus a variable quantity not suitable for measurement. Relaxation of set, the change in size that occurs when a pressed garment is wetted or is first washed, may thus cause a certain amount of area shrinkage. This is reversible on re-pressing and of no serious consequence unless the degree of set has been very considerable. Irreversible shrinkage, which is of great economic importance, is due to felting, a phenomenon resulting from the migration of the individual fibres from their aligned positions in the yarns composing the fabric into surrounding yarns, producing ultimately a compact and inextensible fabric. It is this type of shrinkage (felting) that the several "unshrinkable" processes aim to prevent, and its accurate measurement is necessary in determining the relative merits of the various processes.

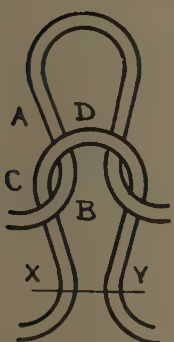
The studies on extensibility have been limited to knitted fabrics, because it is in knitted goods such as socks and underclothes that the easy extensibility is a valued and essential property rapidly impaired by felting. It is characteristic of a knitted fabric that initial extension does not involve the extension of its component yarns. Fig. 1 (*a*) illustrates the plain knit of the fabric used in these experiments. Fig. 1 (*c*) shows the same knit in a stretched condition. The lateral extension has been effected by a change of the distorted and set yarns from the rounded shape of Fig. 1 (*b*) to the flattened shape of Fig. 1 (*c*) without a change in their length. The work done in this type of stretch may be divided into two parts: (*a*) that required to straighten the bent and set yarns, and (*b*) that to overcome the friction between

* An officer of the Council's McMaster Animal Health Laboratory, Sydney, seconded to the Division of Industrial Chemistry.

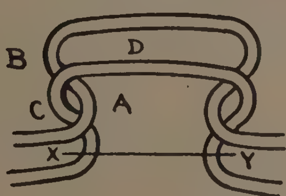
yarns, since all portions of yarn such as AB have been moved relative to the contiguous portions such as CD. Compared with the work of extension of yarn, both these contributions are small, and the point at which yarn extension begins is made evident by a marked increase in the slope of the stress-strain curve. This point was not reached in any of the work to be described, and is not as a rule attained when the garment is worn. The first part of the work of extension (a) can be made practically negligible by soaking the fabric in water to release the set. The effect of wetting on the second component (b) is more complex and requires further analysis, since inter-yarn friction reduces to inter-fibre friction between fibres of contiguous yarns, a quantity which has a complex dependence on the nature of the wetting solution. This matter is still being investigated (5).



(a)



(b)



(c)

FIG. 1.—(a) Photograph of plain type knit. (b) Unstretched form. (c) Stretched form.

A further and larger contribution to the work of extension occurs when the fabric undergoes felting, and this is the basis of the present method of measuring the degree of felting. It is clear that if fibre migration establishes a bridge across the yarn loops in a position such as XY in Fig. 1, then extension of the fabric will involve a stretching of the fibres, a process requiring the expenditure of a much higher order of the work than the components (a) and (b). Felted fabrics thus become more and more difficult to stretch, finally becoming useless.

The count of the yarns, their twist, the number of ply, and the tightness of the knit, influence the extensibility. The tighter the knit and the thicker the yarns, the more effective the contact between yarns in the fabric. This increased contact increases the inter-yarn friction, and consequently increases the work done during extension; it also reduces the rate of felting by impeding the freedom of fibre migration. Any treatment which changes the surface roughness of the individual fibres will reduce the extensibility of the fabric, and this will become more marked with tighter knits. For examining the felting properties of wool it is best to use a loosely knitted fabric in which the frictional factor is less important and felting more rapid.

2. Description of Apparatus and Method.

Evaluation of extensibility may be made by measuring the pressure required to stretch tubular knitted fabrics to a definite size. In the present work, the tubular knitted fabrics described in the preceding paper (3) were studied by inflating within them a small rubber bladder (6 in. long deflated, and 12 in. in circumference at 3 mm. Hg. pressure). Fig. 2 shows the apparatus used, which needs no detailed description. The mercury manometer gave the pressure to the nearest mm. of mercury, and the circumference was measured to the nearest 1/10-in. by means of a tape measure. The relation between inflation pressure and circumference of the bladder alone was first determined and occasionally checked to guard against changes resulting from deterioration of the rubber. An approximate constant rate of inflation must be adhered to, since on standing at constant pressure the circumference slowly increases to a maximum reached in about 15 minutes. To economise in time, inflation at a constant rate was adopted. A similar procedure is customary in stretching fibres.

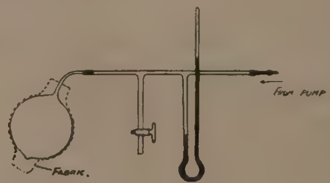


FIG. 2.

If working with air-dry fabrics, the usual care must be taken to condition the sample at a standard humidity. It has been found better to work with wet samples which have been relaxed overnight in distilled water, since this condition can be easily reproduced and maintained

during the inflation. Interpretation of the results is also simplified by using wet fabrics, since the complication introduced by set is eliminated.

The circumference is conveniently plotted as a function of $p - p_b$, where p is the pressure on the manometer when the woollen jacket is on the bladder, and p_b is the reading at the same circumference of the bladder alone. The slope of the curve gives a measure of the extensibility of the fabric and the intercept on the circumference axis the circumference at zero pressure. For purposes of comparison, it has been found convenient to read from the graph the circumference at 20 mm.

3. Some Results.

The work done in stretching knitted fabric has been discussed in Section 1, and the effects of some of the factors mentioned there are illustrated by the curves shown in Fig. 3. These curves were obtained by inflating tubes of a loose three-ply knit of 60's quality wool, all of which originally gave curves near to (*a*). Both wet and dry fabric gave the same curve as far as could be judged in the original untreated and unfelted condition, which means that for this particular knit the reduction in work arising from the release of set has been balanced by an increase due to the increased friction between the wet yarns. A sample of fabric treated with an alcoholic solution containing 6 per cent. KOH and 5 per cent. water for 2 minutes at 25°C. followed by immediate neutralization in dilute aqueous sulphuric acid*, gave the curve (*b*). It is known from other experiments (5) that the fibres after such a treatment have rougher surfaces than before, and it is to this factor that the increased slope of the inflation curve is attributed. After treatment with a recognized softening agent, which reduces the surface friction but affects no other factor, curve (*c*) results. A similar increase in the extensibility of the fabric occurs after a short wash with soap, which also softens the fabric and does not at first cause any appreciable felting in wool treated with KOH. Curve (*d*) is that of an ordinary wool sample after washing for half-hour by the standard method of the preceding paper; some felting and consequent shrinkage took place. The marked increase in the slope is due to the added work component arising from the extension of the migrated fibres, and as has been said, is the basis of the inflation method of estimating the degree of felting. That this is the true explanation was obvious from an inspection of the stretched garment, and was further demonstrated by soaking the sample in a solution which alters the work of fibre extension, e.g., a buffer solution the pH value of which was outside the iso-electric range of wool keratin (pH 5 to 7) (2), but which did not cause a proportionately great change in the other factors contributing to the work function. Curve (*e*) is that of the same fabric after soaking for 8 hours in a buffer solution of pH value 9.2. A similar result is produced by dilute acid.

It will be seen from these examples that, with loose fabrics, the effect of surface friction is relatively small in comparison with that of felting and may be neglected when interpreting the results.

* The Freney-Lipson process (1).

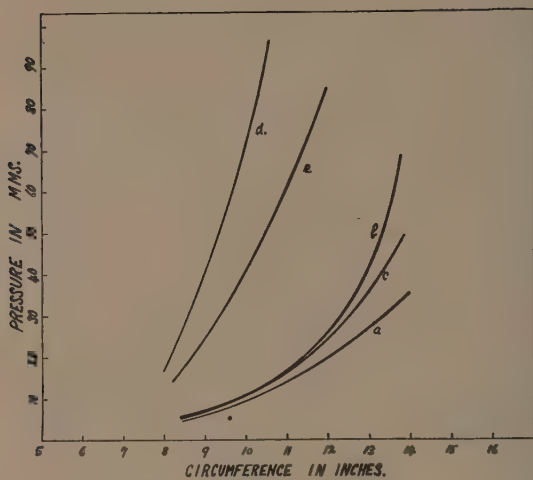


FIG. 3.

This method of determining the felting of woollen materials has been compared with the more common method of measuring area shrinkage in a series of washing tests made in connexion with the development of the Freney-Lipson process for the reduction of shrinkage. Using the capacity of the knitting machine to knit yarns from one- to four-ply (1/18s to 4/18s) with different degrees of tightness, information was also obtained about the different rates of shrinkage of different knits, which confirmed the remarks of Section 1 in this regard. Both area measurements and inflation tests were made on the same cylindrical tubes of knitted fabric. Area measurements were made by allowing the wet relaxed cylinder of material to flatten out to an approximate rectangle (before washing, 3.5 in. × 10 in.) on a sheet of glass, and projecting its shadow on to a superimposed sheet. The area of the shadow was measured by means of a planimeter*. For comparison of different processes of treatment, both methods of assessing the shrinkage are useful, although more can be inferred of the condition of the fabric from an inflation test than from a single area measurement. Both methods usually lead to the same conclusion, but the crossing of the curves in Fig. 5 (washing period of 45 minutes) indicates that circumference reduction and reduction of extensibility are not always equally affected.

Two examples of the applications of the method are given: (*a*) a study of the effect of temperature on the degree of unshrinkability produced by the Freney-Lipson process, and (*b*) a comparison of the Freney-Lipson process and the sulphuryl chloride process.

(*a*) In one experiment a series of loosely knitted tubular fabrics made from 2-ply wool were treated with an alcoholic solution of 7 per cent. KOH containing 5 per cent. water for two minutes, and

* A calculation of area shrinkage from inflation measurements, which would have allowed an exact comparison to be made between the two methods, was not possible because the ratio of length to circumference was not found to be constant for identical fabrics washed under the same conditions.

immediately after treatment each was squeezed and neutralized in 5 per cent. aqueous sulphuric acid. The temperature of the reagent was varied in steps of 5°C. from 15°C. to 35°C. The samples were washed with an untreated (control) sample for an hour in the machine and then inflated. Fig. 4 shows the results.

A rise in temperature obviously increased the effectiveness of the treatment, as shown by the slope of the curves and the intercept on the circumference axis. However, the result obtained at 25°, the temperature preferred from other considerations (3), is considered satisfactory.

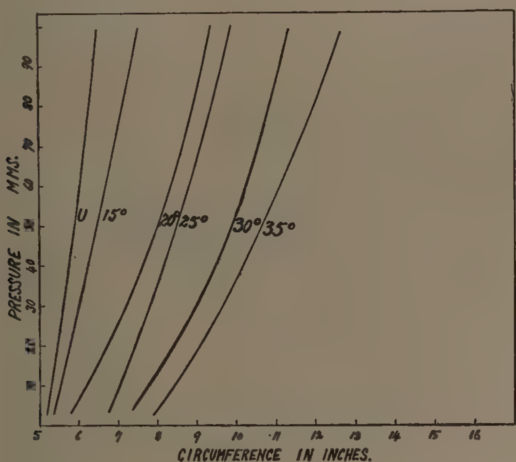
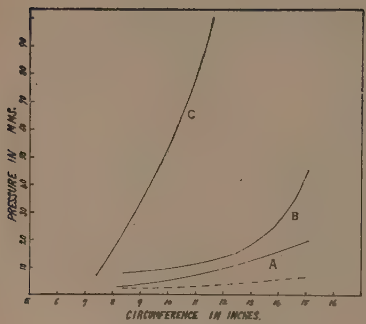


Fig. 4.

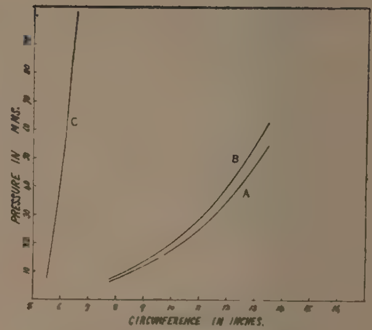
(*b*) The comparison of the Freney-Lipson process and the sulphuryl chloride process was made using 2-, 3- and 4-ply loose knitted fabric and 1-, 2- and 3-ply tight knit, but for the purposes of illustration of the method only the loose 2-ply results will be given.

The treatment with sulphuryl chloride was made with a 2 per cent. solution of this reagent in white spirit; temp. 25°C.; regain 14 per cent.; time of treatment 1 hour(4). The Freney-Lipson treatment was: 7 per cent. KOH and 5 per cent. water in alcohol; temp. 25°C., and time of treatment 2 minutes. Both samples were given four ¼-hour washes, area and inflation measurements being made after each wash. The results of the inflation tests are shown in Fig. 5.

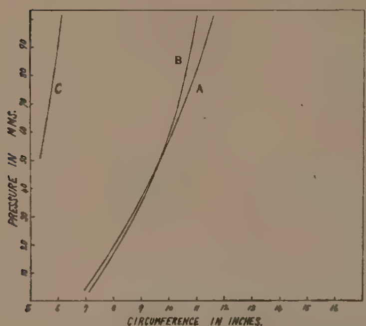
Both processes have reduced markedly the felting rate, and on this test there is little difference between them. The choice has to be made on other grounds, including treatment costs, wearing characteristics, handle, and appearance. With tighter knits the slope of the curve for the sample treated with alkali increases owing to the greater role played by internal friction in fabrics treated this way.



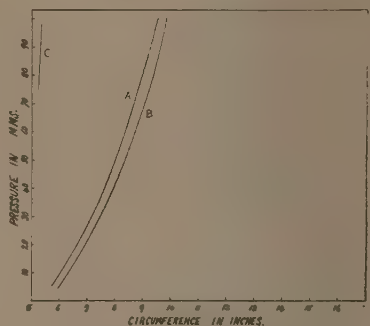
Period of Washing 15 minutes.



Period of Washing 30 minutes.



Period of Washing 45 minutes.



Period of Washing 60 minutes.

FIG. 5.—Comparison of fabrics in successive ½-hour washes. A. Freney-Lipson process. B. Sulphuryl chloride treatment. C. Untreated sample.

4. Acknowledgments.

I wish to acknowledge the help received from my colleagues Messrs. Freney and Lipson, and to thank Mr. E. A. Parrish for taking the photographs.

5. References.

1. Freney, M. R., and Lipson, M.—Coun. Sci. Ind. Res. (Aust.), Pamph. No. 94, 1940.
2. Speakman, J. B., and Hirst, M. C.—*Trans. Farad. Soc.*, 29: 148 (1933).
3. Freney, M. R., and Lipson, M.—This *Journal*, p. 25.
4. Hall, A. J.—*J. Soc. Dyers and Col.*, 55: 389 (1939).
5. Mercer, E. H.—Unpublished work.

Results of Experiments in Fish Canning.

*By E. J. Ferguson Wood, M.Sc., B.A., A.A.C.I.**

1. Introduction.

The results obtained to date from the fish canning experiments carried out by the Fisheries Division are summarized in this report. The primary object has been to discover what Australian fish produce a palatable canned product, and what is the best method of treating them. In some cases the question has been satisfactorily answered, but, in others, considerable further work is indicated. Primarily it was intended to study only the more prolific fish, but latterly the investigation has been extended to estuarine fish which might profitably be canned, especially in war time, by small canneries run on co-operative lines. Such canneries would operate with about a dozen hands, and would require a small boiler of about 10 h.p., a semi-automatic seamer, two small retorts, a simple exhaust box, and possibly a labelling machine, the whole cost of the plant to be in the vicinity of £1,000. Some eighty experiments have been carried out with certain objects in view, but detailed procedure, which is modified only in certain aspects, will not be given for each experiment.

A trade circular† has been published giving the suggested methods for canning various fish, and, while many of these methods were devised as a result of experiments reported here, some further suggestions and modifications have since become obvious. Whereas the trade circular was intended as a guide to canneries working on a moderately large scale, much of the information in this report is applicable only to small canneries. It is contended that, in Australia, the demand for canned fish would be best supplied by large canneries working on tuna, barracouta, and salmon, with smaller canneries packing seasonal fish such as mullet, southern herring, mackerel tuna, bonito, &c. These would give the public a change of menu, while still smaller plants in such locations as Cleveland, near Brisbane, and in Tasmania, possibly canning fruit in season, could pack small quantities of the less abundant yet tasty fish which occur for short seasons in our estuaries. Fish which are useless as fresh fish may be very tasty when canned. An example is the bonito or "horse mackerel" which can be packed to give a delightful pink flesh of a texture and flavour equal to, and very similar to, the better classes of imported salmon. The bony bream, Perth herring or tukari, is another example.

A classification of our more abundant fishes as regards flavour when canned is given below:—

1. *Tuna.*—A first grade product for the discerning palate. This could largely replace or supplement Sockeye salmon.

2. *Bonito.*—A high grade product to replace or supplement pink and Coho salmon and some Sockeye.

---

* An officer of the Division of Fisheries.

† Coun. Sci. Ind. Res. (Aust.), Fisheries Circ. No. 2.

3. *Australian Salmon.*—To replace or supplement the cheaper grades of North Pacific salmon.

4. *Pilchards, Southern Herring, and Tasmanian Sprats.*—These are equal in flavour to, and would replace, imported pilchards, sardines, and sild. They would be packed mainly by the second and third categories of canneries, though a large cannery might operate on pilchards at Port Stephens or Coff's Harbour if fishing boats and gear are available.

5. *Barracouta.*—A high quality fish which can be packed as smoked fish, or with salt or tomato sauce. This would partly serve to replace herrings in tomato sauce and possibly kippers, and has sufficient appeal to be regarded as a new and highly desirable product on the Australian market.

6. *Mullet.*—This fish stands in the same high category as barracouta, but supplies would be limited by several factors.

7. *Crayfish, Crabs, &c.*—There is a limited market for these which could well be supplied from our own waters (e.g., Western Australia).

8. *Shellfish.*—Scallops are canned in Tasmania, but it might be possible to extend this industry. If oyster production could be stimulated, there would be a market for a canned product, smoked or fresh.

Tests on other available species are still being conducted at this Laboratory, and the results will be published from time to time.

2. Experimental.

Canning procedure was carried out by methods which could be adapted to commercial practice, and the fish were handled by a practical fish curer who was well able to assess the comparative ease of preparation of the different species, a matter very difficult of measurement.

The results of the pack were assessed by a tasting panel composed of wives of officers and certain others, who were assumed to represent a cross section of the purchasing public. They were asked to report on vacuum, colour, texture, flavour of the fish in the can, the method of preparation for table, if any, and the flavour of the resulting dish. Marks were to be given for each of these, but the members of the panel found difficulty in assigning numerical values. It was found that in most reports agreement was close, and in cases where widely different opinions were recorded, the result was taken as being poorer than the most favourable report.

An entirely satisfactory method of recording results has yet to be found. If each pack is sampled separately, memories of finer flavours are lost, but if a large number of cans are tasted at once, the palate loses its sensitiveness.

3. Results.

(*a*) *Oyster Canning.*

The oysters (Sydney Rocks) were thoroughly washed and scrubbed and steamed for 40 minutes at temperatures rising from 205° to 220°F. to open the shells. A few of the shells remained closed, but were easily prised open with a knife, and the meat was removed. The oysters were rinsed in a 10 per cent. brine and divided into two lots.

Lot A.—These were spread on a wire tray which had been oiled with cotton-seed oil, placed in a smokehouse at about 110°F. for one hour, packed, and olive oil added.

Lot B.—These were packed in the can and 10 per cent. brine added, leaving $\frac{1}{8}$ inch headspace.

The cans were then exhausted for 15 minutes at about 215°F., seamed, retorted for 60 minutes at 240°F., and cooled.

Both these packs were superior in appearance and flavour to the American and Japanese brands with which they were compared. Better results were obtained by reducing the smoking time to 20 minutes. It required 4 dozen oysters for each $\frac{1}{2}$-lb. can, which, at present prices, represents a cost of about 1s. 6d. per can for the fish.

As these packs were satisfactory, prospective canners could well use the methods, smoking for 20 minutes in the case of the smoked product. This could be done in a tunnel kiln with wire tray or racks moving through the tunnel. The process would then be continuous.

(*b*) *Kingfish of Western Australia, Butterfish of South Australia, and Jewfish of New South Wales and Queensland* (Sciaena antarctica).

(1) The fish was filleted and packed with 1 teaspoonful of salt per can in $\frac{1}{2}$-lb. flat cans. These were exhausted for 15 minutes at 200° to 220°F., seamed, and retorted for 90 minutes at 240°F. (115°C.). They were then cooled.

The appearance of the pack was quite good, the flesh being white, but soft and tasteless. It was not liked by any tasters or by outside critics. The bones were still on the hard side, which made reduction of retorting time impossible. Sample packs of this fish made by commercial interests confirm the idea that it does not process well.

(2) The routine was altered by smoking the fillets for $\frac{3}{4}$-hour prior to packing; though this was an improvement on pack A, the time of smoking was insufficient.

(3) The fish was filleted, skinned, and pickled in 60° brine for $12\frac{1}{2}$ minutes, smoked for 2 hours, and then processed in the usual way. It was of good appearance and flavour and texture was quite good. Presumably the dehydration by brining and smoking prevented the undue softening of the flesh.

It is questionable whether this fish occurs in sufficient concentration to warrant canning on anything approaching a large scale except in Lake Alexandrina. There the price as a fresh fish is usually so high that it would not be profitable. The fact that smoking appears necessary would increase the price of the canned fish.

(*c*) *Australian Salmon* (Arripis trutta).

Although certain laboratory packs of this fish have been considered equal or superior to commercial and experimental products packed elsewhere in Australia, it is felt that a completely satisfactory pack has not yet been prepared. The commercial product from Australian canneries is, however, satisfying a definite section of the market, and appears to be taking a permanent place in Australia's fish supply. There is, however, a toughness of fibre and a peculiar flavour which

does not appeal to certain palates, and which experiments have failed to eliminate. Toughness has been shown to be increased by freezing, fish held for one week at 10°F. being much tougher than the same fish canned immediately after landing. The addition of tomato sauce tends to improve the flavour, but tomato sauce packs have a limited popular appeal. On account of the unsightly nature of the bone, this Division has advocated the filleting of this fish.

Experimental.

(1) Fish were bled and gutted at Narooma and transported to Cronulla. The dark flesh was removed, and half the fish were filleted. Half of each lot was smoked for 2 hours, cut up, and packed in ½-lb. cans. Tomato sauce and salt were added and the fish retorted at 240°F. for 1 hour and then at 250°F. for ½ hour, with controls at 240°F. for 1 hour only. The fish were tough and the bones hard. The unsmoked fish were less tough than the smoked.

(2) Sodium nitrite (0.1 per cent.) was added to cans of freshly filleted fish (1 dessertspoonful per ½-lb. can). A second series was prepared by immersing for 5 minutes in 0.1 per cent. sodium nitrite solution. The cans were retorted at 250°F. for 1½ hours. The resultant packs had a pink exterior, but the flesh was still tough and the flavour only fair.

(3) There were two sections in this experiment—(i) cans packed with tomato sauce and arrowroot, and (ii) cans packed with half a ground anchovy in the can. The retorting time was 1½ hours at 250°F. The anchovy pack was the best to date and had a delicate brown colour which had penetrated through the flesh.

(4) Fresh fish captured locally by trolling were filleted and canned with Italian and Australian anchovies and salt, exhausted at 185°F., seamed, and retorted for 1½ hours at 250°F. These were the best salmon packs and an improvement in flavour on commercial packs. The flesh was comparatively tender and of a uniform brownish colour.

(5) Local salmon canned "chicken haddie" style. The fish were scaled, gutted, and washed, and then placed in saturated brine for 10 minutes. They were precooked at 160° to 185°F. for 45 minutes, and allowed to cool overnight. The white flesh was retained and packed in ½-lb. cans. A small portion of salt was added and the cans were sealed and retorted for 75 minutes at 10-lb. pressure (240°F.). The appearance was rather poor owing to the flaking of the fish. The flesh was white and the fish rather dry, but otherwise very palatable.

(6) A repetition of this experiment was made with the pre-cooker rising from room temperature to 212°F. in 50 minutes and then held at this temperature for 10 minutes. The preliminary brining was inadvertently omitted. The cans were exhausted at 212°F. and retorted for 60 minutes at 240°F. The product was tough, and a further retorting for 60 minutes at 240°F. did not improve this quality. These fish had been frozen and all fish from this source were tough when canned. A second batch with a longer pre-cook (25 minutes after reaching 212°F.) were not any better.

(7) A similar pack with the addition of cottonseed oil and salt was more palatable though somewhat tough.

(8) Further experiments on these fish included a straight pack with salt, one with anchovy and salt, and one with tomato sauce. The retorting times were 90 minutes at 250°F. and 75 minutes at 250°F. The tomato sauce pack retorted for 90 minutes was somewhat tough but otherwise quite good. The shorter time gave a tough product.

(9) Another "chicken haddie" pack with a pre-cook of 45 minutes gave a white pack of good appearance, but the fish were still somewhat tough though less so than in experiment (6). They were no tougher than the commercial packs but would need to be much more palatable to warrant the extra handling.

It has been noticed in sampling commercial packs at this Laboratory that texture varies considerably even in the same batch. This variation of quality appears in smoked "salmon" and seems to be a characteristic of the fish.

(*d*) *Blackfish or Luderick.*

These were gutted, headed, filleted and skinned, and packed with salt in ½-lb. cans. They were exhausted at 200° to 215°F. for 10 minutes, and seamed and retorted at 240°F. for 90 minutes. The loss of weight was about 60 per cent. The product was considered good by some tasters and not liked by others. A second batch was very palatable. The limited occurrence of this fish would make it suitable only for small canneries operating on local fish or for the home canner.

(*e*) *Tailer.*

These were packed after brining in 60° brine for 15 minutes. A second lot was similarly brined and then smoked for 1 hour. The cans were exhausted at 210°F., sealed, and retorted for 75 minutes at 15 lb. pressure (c. 250°F.). Though the appearance was poor and the flesh rather soft the flavour was good. This fish again would be suitable only for local production and consumption.

(*f*) *Clupeoids.*

(i) *Pilchards.*—Two experiments have been conducted with pilchards.

The fish were scaled, headed and eviscerated, hung on tenters and allowed to dry for 1 hour, and smoked for 1½ hours. They were then packed in 1-lb. talls and 2 fl. oz. maize oil and 1 teaspoonful of salt added. The cans were seamed and retorted for 95 minutes at 240°F. The flavour of this pack was excellent but the bones were unpleasantly hard.

In the second experiment the fish were scaled by shaking in a fish basket in salt water, and the heads and viscera were pulled off. The fish were then pickled in 60° brine for 7 minutes and half were smoked for ½ hour on wire trays, the other half being fried for 1 to 2 minutes in cottonseed oil. The fish were then packed in 4- and 8-oz. rectangular cans, olive oil was added, and the cans were retorted at 250°F. for 90 minutes. This resulted in a delightful pack, the smoked being the more tasty. Six fish could be packed into the ¼-lb. and 12 into the ½-lb. cans. The cans were designed by this Division to suit pilchard (sardine) or barracouta packs, and would cost at present rates just over 1d. and 1½d. each respectively, if ordered in sufficient quantity.

(ii) *Southern Herrings.*—These were scaled and eviscerated, washed, brined 5 minutes in a 60° brine, drained, smoked for 15 minutes, and packed, some in olive, some in cottonseed oil. The cans were exhausted at 212°F. and retorted for 90 minutes at about 240°F. The olive oil was considered more pleasant than the cottonseed, but in each case the bones were very hard. In a second experiment the fish were treated in the same way except that half had cottonseed oil added and the rest had only salt added.

These two lots were retorted at 240°F. for 2 hours, which greatly softened the bones. The oil pack was considered an excellent substitute for imported sardines and pilchards. A third test consisting of two unsmoked, one packed with salt alone and the other with tomato sauce after pouring off the liquor, confirmed the fact that 120 minutes at 240°F. is necessary to soften the bones.

These fish are rather more difficult to handle than pilchards, as it is impossible to remove the viscera along with the head, and owing to the shape of the fish, the scaling is not so easy. Southern herring occur in large quantities in the estuaries of the north coast of New South Wales and might prove an important subsidiary to a cannery operating on mullet, bonito, and mackerel tuna in this area.

(iii) *Bony Bream, Tukari, Perth Herring* (*Nematalosa richardsonii*).—These fish were filleted and skinned, pickled for 2½ minutes in saturated brine, and packed in ½-lb. cans. The cans were exhausted at 212°F. Half the cans were then inverted to drain and hot tomato sauce was added. All the cans were then seamed and retorted for 95 minutes at about 250°F. The flesh was pale and soft with very good flavour. It would have been improved by a shorter retorting. A second experiment was made in which the fillets were not skinned, and a 15-minutes dip in a 60° brine replaced the shorter dip in saturated brine. Half of these were smoked for 2 hours and the rest put up as a tomato sauce pack as described previously. Retorting time was 90 minutes at a temperature of 250°F. The product was excellent though the skin was rather tough. The skinning of the large South Australian fish is difficult and not economical, but the smaller Perth herring might be canned with skins left on.

This fish is abundant in estuaries in Western Australia, South Australia, and Queensland, but is rather sporadic in occurrence. It is easily caught and gives a very good substitute for herrings, but is rather difficult to prepare. Preparation would have to be by hand, owing to the mode of occurrence of the fish, but nevertheless a small cannery might well use this fish as a side-line.

(iv.) *Sprats* (*Clupea bassensis*).—The fish were pickled in 80° brine for 10 minutes, headed and eviscerated in one operation, rinsed in the brine, and placed in oiled wire trays. They were dried in the sun and half were fried in cottonseed oil for 5 to 7 minutes, drained, and sun-dried, and the other half were smoked on the trays for 20 minutes. Both lots were packed in ½-lb. cans and 1½ fl. oz. olive oil added to each can. The cans were exhausted, seamed, and retorted for 90 minutes at about 240°F. The product was delicious, very like sild. Possibly the time of frying could be reduced to 2 to 3 minutes and smoking to 10 to 15 minutes for this size fish. These fish occur in Tasmanian waters.

It is thought wise to stress the fact that the importation of canned clupeoid fish (herrings, pilchards, and sardines) into Australia costs about £500,000 p.a. and that this represents about 4,000 tons of canned fish. Part of this can be replaced by canned barracouta, but this would probably leave a margin to be replaced by Australian clupeoids. On present knowledge, an attempt to supply this margin could be made only by a group of small canneries working on southern herring, Tasmanian sprats, and possibly pilchards and anchovies, and aiming at a production consuming about 20 tons of raw fish per week. Mullet, crabs, crayfish, bonito, &c., could be used, when available, in the off-season.

(*g*) *Scombroids and Their Allies.*

(i) *Bonito.*—The following experiments were carried out:—

(1) The fish were packed tuna style. A pre-cook of 20 minutes at temperatures rising from 60° to 195°F. was found too short for these fish, which weighed from 2 to 4 lb. They were given an extra 20 minutes at 212°F., but this rather overcooked them, and they were left too soft and cheesy.

(2) These fish weighed from $3\frac{1}{2}$ to 5 lb. without heads and were pre-cooked for 50 minutes at temperatures from 60° to 212°F. and at 212°F. for 25 minutes. They were then canned tuna style and gave a very good product.

(3) Fish of 1 to $2\frac{1}{2}$ lb. were steamed for $\frac{3}{4}$ hour with temperatures from 60° to 212°F., packed tuna style, and gave an excellent product.

(4) Fish of the same weights steamed for an additional 15 minutes at 212°F. were canned tuna style. The product was very good.

(5) Another similar experiment gave the same results.

(6) Bonito packed mackerel style without the pre-cook were delicious, and tasted like good quality salmon. The flesh was pale pink and of salmon texture. This type of pack has great possibilities provided the fish can be caught in sufficient quantity. A second and third experiment confirmed the excellence of this method.

(ii) *Mackerel.*—After scaling, gutting, heading, and tailing, these fish were packed in $\frac{1}{2}$-lb. cans, salt was added, and the cans were exhausted, seamed, and retorted at 240°F. for 90 minutes. The results were most promising.

A second and similar pack was not so successful. The fish were too loose and were discoloured.

A third experiment using 1-lb. cans was made, part smoked, part in tomato sauce, and part in American style. The flavour of each pack was excellent, and this fish packed as kippers (smoked 1 hour) or in tomato sauce in oval cans would be a very fine substitute for herrings. The possibilities of this fish are, technologically at least, very great.

(*h*) *Yellowtail (Kingfish)*.

These were canned tuna style with a pre-cook of 20 minutes at 185° to 212°F. and cooled for 2 hours. The fish weighed 1 to 2 lb. Some more fish were canned without the pre-cook, cottonseed oil was added, and the cans were retorted. The small flakes made the pack unsightly and the flavour was not particularly good.

A second batch of three fish weighing 6, 10, and 20 lb. were canned tuna style. Pre-cooking times were: 20-lb. fish 2½ hours, 6- and 10-lb. fish 1½ hours. The cooker took 1 hour to reach 212°F. The fish were cooled overnight and the flesh was removed, cut up, and packed. The cans were retorted at 240°F. for 75 minutes. The appearance was rather poor owing to the flaky nature of the flesh and the taste not as good as that of tuna or mackerel. Some toughness was apparent.

(*i*) *Mullet*.

A number of experiments have been carried out in the canning of this fish, and only a brief summary of the results will be given.

(1) The fish were brined for various times prior to canning, and 1 per cent. acetic acid was added to one lot. At the same time some fish were salted and fried in maize oil in the can, and some packed with cottonseed oil and salt. The oil packs were rather less palatable than the others, and the acetic acid pack was the best. As the retorting time was 75 minutes at 240°F., the bones were still hard.

(2) Half the fish were smoked for 1 hour and the other half left unsmoked. Anchovy sauce was added to half the smoked, and half the unsmoked fish, and tomato sauce to the other half, making four lots in all. The cans were retorted at 250°F. for 45 minutes or 240°F. for the same period, giving eight lots of cans. It was found that the bones were still hard at these temperatures, while smoking appeared to toughen the flesh.

The anchovy sauce gave an unpalatable pack while the tomato sauce pack much resembled herrings in tomato sauce.

(3) "Chicken haddie" pack. This was done in a manner similar to that for salmon (see p. 50). It resembled crab in flavour and appearance, but the result would not warrant the expense involved in the method.

(4) A further experiment with the following additions was carried out:—

(*a*) Half teaspoonful of powdered agar and salt.
(*b*) Ground anchovy and salt.
(*c*) Tomato sauce and salt.
(*d*) Liquid essence of smoke and salt.
(*e*) Salt only.

Of these the last two were the best packs and the agar pack was not popular. Retorting at 240°F. for 90 minutes softened the bone adequately in this pack. The presence of "curd" marred the appearance of the pack, so a preliminary brining was tried.

(5) Half the fish acted as controls, and the rest were pickled in an 80° brine for 5 minutes. All were packed (some in tomato sauce), salt was added, and the cans were retorted at 240°F. for 75 minutes. This time was insufficient and the bones were still hard.

(6) After a 5 minutes pickle of the cut pieces in 100° salinometer brine the fish were packed and the cans exhausted for 20 minutes, seamed, and retorted at 240°F. for 90 minutes. The flesh was very tender but the bones slightly hard. Curd was reduced to some extent in the brined cans. A similar test was made with a tomato sauce pack, and in this case also the bones were hard. Curd was not entirely overcome by brining.

(7) A further experiment was made with part of the fish brined 15 minutes in 60° pickle and smoked for 1½ hours. The other part had salt added, and some cans had hot tomato sauce added to the drained cans. The retorting time was 90 minutes at 240°F. In this case the bones were soft. The least interesting pack was the smoked fish, as a certain toughening seems to take place in the smoking. The other packs were very good, the tomato sauce pack being equal or superior to imported herrings in tomato sauce.

(8) The fish were prepared, cut up, and half were dipped for 5 minutes in a saturated brine with 1 per cent. sodium phosphate; the other half had vinegar added (1 tablespoonful per can). These cans were exhausted, seamed, and retorted as usual. The sodium phosphate apparently precipitated the proteins in the flesh and removed the curd, but altered the appearance of the flesh to the detriment of the pack. The acetic acid pack had slight curd and a cloudy liquor, but was more palatable.

(*j*) *Barracouta.*

(1) The fish were filleted, skinned, and pickled in a 60° brine for 7 minutes. One third of the fish were smoked and one third had a small quantity of "essence of smoke" added. All the fish were then packed in ½-lb. flats. The cans were exhausted and seamed and retorted for 75 minutes at about 240°F. This pack was very good, though the shape of the can was not adapted to the fish. The smoked fish was the best.

(2) The fish were filleted, skinned, and pickled as above, and smoked for 1 hour, cut up and packed in 1 lb. rectangular cans, seamed without exhausting, and retorted at 240°F. for 90 minutes. The shrinkage was fairly great, and curd somewhat spoiled the appearance of the pack which was otherwise excellent in every way.

(3) Four lots were used. One of these was packed with tomato sauce, one left plain, and one smoked for ¾ hour. These three were then subjected to a dip in 60° brine containing 1 per cent. sodium phosphate to reduce curd. The fourth lot was canned with 1 tablespoon of 1 per cent. acetic acid per can. The cans were retorted for 100 minutes at about 240°F. The acetic acid pack was not as good as the others and curd was present. The other packs had a very good appearance and flavour and found general approval.

(4) The acetic acid pack was eliminated in this batch and treatment was otherwise as for Experiment 3; ½-lb. and ¼-lb. rectangular flat cans were also put up in this batch. The loss of weight of headed and gutted fish was about 25 per cent.

(5) Some fish were also packed as cutlets without skinning and were as palatable though not nearly as good in appearance as those in the rectangular cans. The loss of weight of the gutted and headed fish was less than 5 per cent.

These results show that it is possible to can barracouta to produce a very high class product, and that there is little difficulty in the process.

(*k*) *Tuna.*

The tuna were all canned according to the methods described by Roedel, i.e., gutted, pre-cooked, the flesh broken out, cut, and packed. Cottonseed oil (1 to 2 fl. oz.) and salt (1 tablespoon) were added per ½-lb. can. The fish were retorted at about 240°F. for 75 minutes.

Much of the canning of this fish has been for trade samples, though experiments have been conducted to determine the optimum pre-cooking time and weight losses. The methods have been described in Fisheries Circular No. 2 of this Division, so that experiments need not be given in detail here.

The results give a fairly clear indication of the time required for pre-cooking fish of various weights. The optimum times are tabulated below :—

Weight of Fish. lb.	Precooking Time. Fish Placed in Retort at Room Temperature.		Fish Placed in Retort at 220°F.
	Time Taken for Temperature to reach 220°F.	Temperature Maintained at 220°F. for :—	Temperature Maintained at 220°F. for :—
1–4	45–60 mins.	15–30 mins.	..
5–9	,, ,,	30–60 ,,	60 mins.
10–12	,, ,,	60–90 ,,	60 ,,
12–18	,, ,,	2–3 hrs.	3–4 hrs.
18–25	,, ,,	2–3 ,,	..

These figures are the results of tests on 83 fish, mostly of the 5 to 9 lb. class, but it is hoped to extend these observations and study further relationships between time of pre-cook, loss of weight, and flavour. The longer the pre-cook the greater is the loss of weight; hence the time of pre-cook must be as short as is consistent with tenderness and good flavour.

Varieties canned experimentally include albacore, striped tuna (skipjack), bluefin (*T. maccoyii*), northern bluefin (*Kishinoella tonggol*), and mackerel tunny.

A Modified Apparatus for Fish Scale Reading.

By G. L. Kesteven B.Sc., and Andrew Proctor.**

The use of scale reading in the determination of the age of fish is a normal procedure in fisheries research (when the scales are readable). The usual technique is to estimate the age of the fish from the number of year zones shown by the scales and then to measure the width of a major axis of the scale and of the successive zones along that; from these widths, and the length of the fish from which the scale is taken, simple proportion calculations are made according to the formula—

$$L' = \frac{L \times l'}{l}$$

where L equals the length of the fish from which the scale was taken, L' equals the length of the fish when the scale was of length l', and l equals the length of the major axis of the scale. In this way the length of the fish at the end of each year prior to capture may be calculated. The value of this work lies in its use for estimation of growth rate, and in checking the age reading against observed lengths.

Hitherto, in this Laboratory, the method has been to use a simple direct projection of the image of the scale through a horizontal microscope on to a vertical screen; from this projected image the lengths of the year zones and of the major axis were marked off along a strip of paper. From this strip of paper the intermediate lengths were read off by use of a special board involving simple proportions between parallels†.

A modification of this apparatus has recently been evolved here. It is shown in Plate 3, Figs. 1 and 2. The first feature‡ is the use of a millimetre grid on the screen so that, when the image is thrown upon the screen, the lengths of the zones on the scale can be read off directly.

The second feature is the movability of the screen which is fitted to slide easily on rods and is propelled steadily by means of a long worm drive (see Plate 4, Fig. 1). The purpose of this is that by moving the screen the image of the major axis can be made equal to the length of the fish, thus producing a direct proportionality between the scale and the image equal to that between the scale and the fish. Therefore the intermediate lengths can be read off directly upon this screen without any calculations. This, it will be seen, eliminates the labour and time of cutting and marking the paper strips and of calculating from them, and it also eliminates a possibility of error in marking the strips and in calculating from them. It, of course, makes the danger of bias more real, but it should be possible to eliminate this. In order to accommodate scales of all sizes, a series of millimetre grids in which 1 mm. = ½, 1, 2, 3 and 4 mm. should, with combinations of eyepieces and objectives, cover most requirements.

* An officer of the Division of Fisheries.

† The apparatus has been described and figured by Thompson and Lindsay (1932); the method is that of Lea (1919).

‡ This modification alone can be made very useful where it is not possible to have the screen made movable. The magnification of the scale may be neglected and the length of the various zones and of the major axis noted as projected. Then, using a slide rule by continuous process, the length of the fish is divided by the length of the scale, and then the factor so obtained is multiplied by the successive zone widths simply by sliding the cursor.

This method of calculation of intermediate lengths depends upon the assumption that the relation between scale size and fish length may be expressed by one constant linear regression equation, and this apparatus does not remove the obligation in each case to prove this assumption by such methods as those discussed by Buchanan-Wollaston (1934).

The third feature of the apparatus is the provision of a millimetre scale on the table under the screen and parallel with the line of movement of the screen. A pointer on the bottom edge of the screen indicates the distance between the screen and the microscope. The relationship between this distance and the magnification of the image is linear, and graphs have been prepared for the various combinations of eyepieces and objectives, so that actual magnification can be read off with ease. This is of value where it is desired to test the linearity of the relation of scale size and fish length, for the back calculation to actual scale size is easy.

Technical Description.

The apparatus is built up from a Metron Reflex Drawing Apparatus (without prism) and the simplest type of microscope. We use a Watson & Sons "Kima." The complete unit consists of a 6-ft. × 3-ft. table with the projection apparatus mounted horizontally at the right and the movable screen at the left. Undesirable light reflections are eliminated by housing the projection apparatus completely in a compartment 12 in. × 27 in. × 18 in. This wooden cover is partly lined with $\frac{1}{8}$-in. thick asbestos sheet around the lamp, and a 3-in. vent directly over the lamp provides adequate ventilation. A close fitting aperture just allows the microscope eyepiece to protrude when necessary, and directly opposite the stage a 6-in. × 6-in. hinged door is used for operating.

The 23-in. × 29-in. movable screen is made of 2-in. × 1-in. timber, and ordinary 20-oz. window glass. The runners are $\frac{3}{8}$-in. brass rod 3 feet long and mounted 2 inches from the surface of the table on $\frac{3}{4}$-in. brass posts. Brass tubing of $\frac{3}{8}$-in. internal diameter provides very efficient bearings and is fixed to the leg supports of the screen. This obviates any but the movement required. Propulsion is by a $\frac{3}{8}$-in. × 3-ft. threaded brass rod, and a 3-in. brass disc handle. A small thread, 24 to 1 inch (S.A.E.), is used for accurate adjustment. This rod is also mounted on $\frac{3}{4}$-in. brass posts, and runs through a tapped brass plate which is bolted to the centre of the bottom of the screen frame. Details are shown in Plate 4, Fig. 1.

A boxwood metre stick is fixed at a convenient angle under the screen, to which a brass pointer is attached. The apparatus is wired as a unit and can be plugged into any dark room. Two switches allow the operator to control the projection lamp and the reading lamp independently. A simple slide carrier made of brass (Plate 4, Fig. 2) is just as suitable and much less expensive than a mechanical stage.

References.

Thompson, H., and Lindsay, S. T. (1932).—Newfoundland Dep. Nat. Resources, Fish. Res. Bull. No. 1.

Lea, E. (1919).—Canadian Fisheries Expedition, 1914-15, Ottawa.

Buchanan-Wollaston, H. J. (1934).—Cons. Perm. Int. pour l'Explor., de la Mer. Rapp. Proc.-Verb. 89, III., (4): 33.

Interplant Competition in Mixed Wheat Populations and its Relation to Single Plant Selection.

By C. S. Christian, M.Sc., B.Sc.Agr. and S. G. Gray, B.Sc.Agr.**

Summary.

An experiment has been conducted to determine the magnitude of the effects of competition between plants upon characters associated with yield of grain in heterogeneous wheat populations sown at field spacings.

It has been demonstrated that unequal competition between plants exists, and that it is associated with seed weight and rate of growth, the characters most affected being tiller number, ear number, and yield of grain. The results of this competition are sufficiently great to account for the fact that single plant selection, as usually practised, for yielding ability in segregating generations of wheat crosses has been ineffective.

Methods which aim at improving the technique of single plant selection should take this source of variation into account. Several possible changes in technique are suggested. Much of the variation due to interplant competition could be eliminated by grading the seed according to size or weight, and sowing only seed of approximately the same weight in one plot. Interplant competition from all sources could be eliminated by using a much wider spacing than at present adopted, but this would be very different from normal field conditions. Allowance for the effects of interplant competition might also be made by the use of statistical methods, for example, in this experiment a statistical correction based on time of maturity would have assisted in differentiating the genotypes for average weight per grain.

1. Introduction.

Wheat breeding necessitates planned crossing of varieties, and the selection of desirable segregates in some later generation. At some time or other use must be made of individual plant selections from a segregating population. Experiments to determine the most reliable way of making these have been in progress at Canberra since 1932.

The observed variation among individual plants in the progeny of a cross is due to the combined effect of genetic segregation and environmental variation. The latter includes not only variation in the micro-environment but also such environmentally influenced factors as those affecting seed development and competition between plants.

In preliminary experiments in which F_2 generations were sown at approximately field spacings, it soon became apparent that much of the variation in actual yield of adjacent plants was due to competition, apart from any inherited variation in yielding ability.

One factor likely to influence competitive ability is initial seed size. It was shown by McMillan* that within a pure line of wheat, yields of individual plants at close spacings were influenced by factors associated with seed weight and early growth; 24 per cent. of the variance of yield was accounted for by correlated variation in those characters. The effect was mainly through ear number, but also through average grain

---

* An officer of the Section of Plant Genetics, Division of Plant Industry.

* McMillan, J. R. A., Predetermination as an influence on yield in wheat plants. *J. Coun. Sci. Ind. Res.* (Aust.), 8: 1-7 (1935).

weight. The influence of seed weight upon early growth was evident, for a significant correlation ($r = + 0.28$) was obtained between that character and height of plant taken 16 days after sowing pre-germinated seed.

Unpublished data obtained by the authors with two varieties of wheat, Comeback and Cleveland, showed that a significant fraction (6 to 8 per cent.) of the variance of yield between plants grown at a spacing of 6 inches by 2 inches was accounted for by variation in seed weight, when ungerminated seed was sown. The data also indicated that when the influence on tiller number had been statistically eliminated there was very little additional effect upon yield (see table below).

Variety.	Percentage of the Total Variance of Yield Accounted for by—		
	Seed Weight.	Tiller Number.	Seed Weight and Tiller Number.
	Per cent.	Per cent.	Per cent.
Comeback	7·9	67·7	68·5
Cleveland	6·3	71·3	71·3

All results significant.

Other data obtained from indoor experiments have given correlation coefficients as high as +0.7 between seed weight and the total length of the first two leaves, indicating that an effect is produced very early in growth.

Another possible factor influencing the competitive ability of a plant, and likely to occur in material of segregating generations, is a difference in rate of growth between adjacent plants, such as may occur when genotypes of different potential maturity are grown together.

2. Material and Methods.

The experiment was designed to examine the effects of the following factors on competitive ability:—

(*a*) Seed size;
(*b*) Time of maturity;
(*c*) Combination of seed size and time of maturity.

Two varieties of wheat, Early Bird and Cleveland, were chosen as early and late maturing wheats respectively, the difference in date of maturity observed in this experiment being 17 days. Samples of small and of large seed of each variety were obtained by sieving and hand picking, excluding all broken or shrivelled grain. The average weights per grain were 27 milligrammes for the small seed and 45 milligrammes for the large seed in each variety.

The following 10 types of plot were sown:—

1. Small seed of Early Bird sown alone.
2. Large seed of Early Bird sown alone.
3. Small seed of Cleveland sown alone.
4. Large seed of Cleveland sown alone.
5. Small and large seed of Early Bird sown alternately.
6. Small and large seed of Cleveland sown alternately.

7. Small seed of Early Bird and Cleveland sown alternately.
8. Large seed of Early Bird and Cleveland sown alternately.
9. Small seed of Early Bird and large seed of Cleveland sown alternately.
10. Large seed of Early Bird and small seed of Cleveland sown alternately.

Test plots consisting of 3 rows, each 3 feet long and 6 inches apart, with seed 2 inches apart in the rows, were planted accurately with the Engledow dibbler. Alternate seeds of types to be compared for competition were sown in the same row. Each of the 10 major plots was subdivided into two minor plots on this basis. Five replications were sown, giving, for the major plots, a 5-column by 10-row arrangement. The plots within the columns were arranged at random, with the restriction that each successive pair of rows included all combinations, making a semi-Latin square arrangement for rows and columns.*

In all plots, whether sown entirely with one type of seed or with two types alternately, the odd and even numbered plants were harvested as separate minor plots.

The material was sown at Canberra on 7th May, 1935, ungerminated seed being used. Early Bird was harvested on 13th December, and Cleveland on 30th December. Data on the following characters were obtained:—

T_1—Early tiller number; totals per plot on 2nd July.
T_2—Final tiller number; totals per plot on 25th September.
E—Total number of ears per plot.
n—Average number of grains per ear.
g—Average weight per grain expressed in milligrammes.
Y—Total yield of grain per plot expressed in grammes.

It will be observed that in each of the first four types of plots, which are control plots sown with one type of seed only, the odd and even numbered plants both provide information upon the same material. For simplicity of statistical analysis, the two halves obtained by harvesting these separately were regarded as different treatments, giving, in the analysis, 20 treatments, distributed in pairs in ten major plots. For comparison with other treatments the two halves of the control plots were grouped. The arrangement enabled 16 types of competition to be examined, as follows:—

Test Material.		Type of Competition.			
		Early Bird (early).		Cleveland (late).	
Variety.	Seed Size.	Small Seed.	Large Seed.	Small Seed.	Large Seed.
Early Bird ..	Small ..	1	2	3	4
	Large ..	5	6	7	8
Cleveland ..	Small ..	9	10	11	12
	Large ..	13	14	15	16

* Yates has since shown that this arrangement is not altogether satisfactory, since it introduces a small bias into the estimate of error. Complex Experiments.—Supp. to *J. Roy. Stat. Soc.*, 2 (2): 245 (1935).

From each competition plot, sown with two types of seed alternately, it was possible to obtain information upon two of these combinations.

After the analysis of variance had established significant effects, the *t*-test was used to compare actual differences. Different estimates of error were involved when comparing minor plots, according to whether they occurred in different or the same major plots, there being 32 degrees of freedom available for the former, and 40 for the latter. This is indicated in the following analysis:—

ANALYSIS OF DEGREES OF FREEDOM.

——	Between Minor Plots.	Between Major Plots.	Within Major Plots.
Columns	4	4	..
Rows	4	4	..
Treatments	19	9	10
Error	72	32	40
Total	99	49	50

3. Results.

Detailed data for all characters observed are presented in Tables 1 to 4.

(*a*) *Large and Small Seed Sown Alone.*

There were no significant differences between small seed sown alone and large seed of the same variety sown alone, except in the early tiller count in Cleveland, in which there was a significant difference in favour of large seed. This initial advantage was not reflected in later characters. Apart from this one instance, there was no evidence that small and large seed sizes produced different effects when sown alone.

(*b*) *Large and Small Seed Sown in Competition.*

When large and small seed were sown in competition, differences in favour of large seed were observed in all characters in both varieties. The differences were statistically significant for final tiller number, ear number, and yield, in the early variety, and for early and late tiller number, ear number, and yield, in the late variety.

It is evident that large seed has a competitive advantage over small seed when the two are sown alternately.

(*c*) *Early and Late Varieties Sown Alone.*

The early and late varieties differed in date of maturity by 17 days. The early variety gave more ears, a higher average grain weight, and a higher yield. The late variety produced more tillers and more grains per ear. These differences were consistent for both seed sizes, but were not statistically significant in all cases.

TABLE 1.—EFFECT OF DIFFERENCE IN SEED SIZE IN EACH OF TWO VARIETIES.

Character.	Manner Sown.	Small Seed Versus Large Seed.							
		In early Variety.				In Late Variety.			
		Small.	Large.	Diff.	P.*	Small.	Large.	Diff.	P.
T_1	In competition	32·6	34·2	— 1·6	·7	35·6	48·8	—13·2	< ·01
	Alone ..	35·5	34·1	1·4	·7	39·1	49·1	—10·0	< ·01
	Difference ..	— 2·9	0·1	..	..	— 3·5	— 0·3	..	..
	P	·5	·9	..	..	·4	·9	..	..
T_2	In competition	132·4	167·2	—34·8	< ·01	209·0	289·8	—80·8	< ·01
	Alone ..	158·8	154·4	4·4	·7	246·8	247·1	— 0·3	·9
	Difference ..	—26·4	12·8	..	..	—37·8	42·7	..	..
	P	·1	·4	..	..	·01	·01	..	..
E	In competition	68·2	91·2	—23·0	< ·01	52·6	88·0	—35·4	< ·01
	Alone ..	87·2	78·3	8·9	·1	66·8	63·5	3·3	·6
	Difference ..	—19·0	12·9	..	..	—14·2	24·5	..	..
	P	< ·01	·05	..	..	·05	< ·01	..	..
n	In competition	22·64	24·08	— 1·44	·4	26·40	28·70	— 2·30	·2
	Alone ..	23·85	22·99	0·86	·6	25·15	24·68	0·47	·8
	Difference ..	— 1·21	1·09	..	..	1·25	4·02	..	..
	P	·5	·5	..	..	·5	·02	..	..
g	In competition	41·110	41·460	— ·350	·8	39·640	38·180	1 460	·3
	Alone ..	40·495	41·470	— ·975	·5	37·240	38·995	— 1·715	·2
	Difference ..	0·615	— 0·010	..	..	2·400	— 0·775	..	..
	P	·9	·9	..	..	·6	·9	..	..
Y	In competition	62·60	90·58	—27·98	< ·01	55·44	94·60	—39·16	< ·01
	Alone ..	83·86	74·61	9·25	·3	63·51	60·94	2·57	·8
	Difference ..	—21·26	15·97	..	..	— 8·07	33·66	..	..
	P	·05	·1	..	..	·4	< ·01	..	..

P = probability of exceeding the value of t by chance.

Tables 1 to 3 give values for plant characters obtained from plots of uniform material sown .one, and from plots in which two types were sown in alternate positions and thus in competition. or example, in Table 1, in the early variety, when plots were sown entirely with small, or with rge, seed, the yield was 83·86 and 74·61 grammes per plot respectively. In plots in which nall and large seed of the early variety were sown in competition with each other, material ised from small seed yielded 62·60 grammes per plot and material raised from large seed yielded)·58 grammes per plot.

TABLE 2.—EFFECT OF DIFFERENCE IN VARIETY IN EACH OF TWO SEED SIZES.

Character.	Manner Sown.	Early Variety Versus Late Variety.							
		In Small Seed.				In Large Seed.			
		Early.	Late.	Diff.	P.	Early.	Late.	Diff.	P.
T_1	In competition	32·0	36·6	− 4·6	·2	37·4	47·0	− 9·6	<·0
	Alone ..	35·5	39·1	− 3·6	·3	34·1	49·1	−15·0	<·0
	Difference ..	− 3·5	− 2·5	..	..	3·3	− 2·1	..	..
	P	·4	·6	..	..	·4	·6	..	..
T_2	In competition	145·4	222·4	− 77·0	<·01	175·8	249·4	−73·6	<·0
	Alone ..	158·8	246·8	− 88·0	<·01	154·4	247·1	−92·7	<·0
	Difference ..	−13·4	−24·4	..	..	21·4	2·3	..	..
	P	·4	·1	..	..	·2	·9	..	..
E	In competition	65·0	74·2	− 9·2	·1	84·2	77·2	7·0	·2
	Alone ..	87·2	66·8	20·4	<·01	78·3	63·5	14·8	<·
	Difference ..	−22·2	7·4	..	..	5·9	13·7	..	..
	P	< ·01	·2	..	..	·3	·05	..	..
n	In competition	20·84	24·26	− 3·42	·02	21·74	26·92	− 5·18	<·
	Alone ..	23·85	25·15	− 1·30	·4	22·99	24·68	− 1·69	·2
	Difference ..	− 3·01	− 0·89	..	..	− 1·25	2·24	..	..
	P	·1	·6	..	..	·5	·2	..	..
g	In competition	38·400	39·820	− 1·420	·3	37·860	38·410	− 0·550	·7
	Alone ..	40·495	37·240	3·255	·01	41·470	38·955	2·515	·0
	Difference ..	− 2·095	2·580	..	..	− 3·610	− 0·545	..	..
	P	·7	·6	..	..	·5	·9	..	..
Y	In competition	52·64	73·24	−20·60	<·01	69·30	78·82	− 9·52	·2
	Alone ..	83·86	63·51	20·35	·02	74·61	60·94	13·67	·1
	Difference ..	−31·22	9·73	..	..	− 5·31	17·88	..	..
	P ..	< ·01	·3	..	..	·6	·1	..	..

(*d*) *Early and Late Varieties Sown in Competition.*

The data indicate that the late variety Cleveland was an effective competitor against the early variety Early Bird. For example, Early Bird out-yielded Cleveland in the control plots by an average of 27 per cent. When sown in competition, Cleveland out-yielded Early Bird by an average of 24 per cent. Both of these differences are statistically significant.

As the Early Bird material was harvested 17 days before Cleveland, it might be expected that the competitive advantage of Cleveland could be partly explained by the consequent reduction in the competition for water during the later stages of grain filling. The data do not support

TABLE 3.—EFFECT OF DIFFERENCE IN BOTH SEED SIZE AND VARIETY.

Character.	Manner Shown.	Variation in Both Seed Size and Variety.							
		Small Seed of Early Variety Versus Large Seed of Late Variety.				Small Seed of Late Variety Versus Large Seed of Early Variety.			
		Small Early.	Large Late.	Diff.	P.	Small Late.	Large Early.	Diff.	P.
T_1	In competition	33·8	49·0	—15·2	<·01	36·4	37·8	— 1·4	·7
	Alone ..	35·5	49·1	—13·6	<·01	39·1	34·1	5·0	·2
	Difference ..	— 1·7	— 0·1	..	..	— 2·7	3·7	..	..
	P	·7	·9	..	..	·5	·4	..	..
T_2	In competition	139·6	256·2	—116·6	<·01	203·2	183·6	19·6	·1
	Alone ..	158·8	247·1	—88·3	<·01	246·8	154·4	92·4	<·01
	Difference ..	—18·7	9·1	..	..	—43·6	29·2	..	..
	P	·2	·6	..	..	·01	·05	..	..
E	In competition	66·0	84·8	—18·8	<·01	65·6	99·0	—33·4	<·01
	Alone ..	87·2	63·5	23·7	<·01	66·8	78·3	—11·5	·05
	Difference ..	—21·2	21·3	..	..	— 1·2	20·7	..	..
	P	< ·01	< ·01	..	..	·8	< ·01	..	..
n	In competition	20·70	27·90	— 7·20	<·01	26·20	22·94	3·26	·05
	Alone ..	23·85	24·68	— 0·83	·6	25·15	22·99	2·16	·1
	Difference ..	— 3·15	3·22	..	..	1·05	— 0·05	..	..
	P	·1	·1	..	..	·6	·9	..	..
g	In competition	38·320	39·780	— 1·460	·3	38·270	38·700	— 0·430	·7
	Alone ..	40·495	38·955	1·540	·2	37·240	41·470	— 4·230	<·01
	Difference ..	— 2·175	0·825	..	..	1·030	— 2·770	..	..
	P	·7	·9	..	..	·8	·6	..	..
Y	In competition	52·20	94·94	—42·74	<·01	65·94	87·26	—21·32	<·01
	Alone ..	83·86	60·94	22·92	<·01	63·51	74·61	—11·10	·2
	Difference ..	—31·66	34·00	..	..	2·43	12·65	..	..
	P	< ·01	< ·01	..	..	·8	·9	..	..

this. There is no indication that the average weight per grain in Cleveland increased in the competition plots. The increase in yield is accounted for mainly by a significant increase in number of ears.

(e) Seed Differing in Both Seed Size and Variety.

Plots in which seed differing in both seed size and variety occurred in competition were of two types: first, small seed of the early variety sown in competition with large seed of the late variety; second, small seed of the late variety sown in competition with large seed of the early variety.

From the observations already made on the effects of seed size and variety, it is to be expected that in the first instance both factors would act in the same direction to increase the total effect, whereas in the second they would tend to counteract each other. The mean difference for yield in favour of large seed in competition is 33.57, and in favour of the late variety in competition is 15.06. The sum and difference respectively between these values represent the theoretical difference between (*a*) small seed of the early variety and large seed of the late variety in competition, and (*b*) small seed of the late variety and large seed of the early variety in competition. The calculated values thus obtained were 48.63 and 18.51 respectively. The observed values were 42.74 and 21.32 respectively, indicating that the two factors were cumulative in their effects.

The average effects of each of the two types of competition are expressed, in terms of difference from values of the control plots in per cent., in Table 4.

TABLE 4.—SUMMARIZED EFFECTS OF TWO TYPES OF INTERPLANT COMPETITION.

Character.	Average Effect on Small Seed by Competition from Large Seed.		Average Effect on Large Seed by Competition from Small Seed.		Average Effect on Early Bird by Competition from Cleveland.		Average Effect on Cleveland by Competition from Early Bird.	
	Effect in Per cent.	P.	Effect in Per cent.	P.	Effect in Per cent.	P.	Effect in Per. cent.	P.
T_1	− 8·6	·3	− 0·2	·9	− 0·3	·9	− 5·2	·5
T_2	−15·8	<·01	13·8	·01	2·6	·7	− 4·5	·3
E	−21·6	<·01	26·4	<·01	− 9·8	·1	16·2	·02
n	− 0·2	·9	10·7	·05	− 9·4	·1	2·6	·6
g	3·9	·2	− 1·0	·7	− 7·0	·01	0·04	·9
Y	−19·9	·05	36·6	<·01	−23·1	·01	23·2	·05

4. Discussion.

It is evident that each factor, seed size and time of maturity, had a pronounced effect upon certain plant characters. The characters most affected were tiller number, ear number, and yield of grain. The ear characteristics, grains per ear, and weight per grain, were not consistently affected, changes usually being small. Early Bird showed a significant reduction in weight per grain of 7 per cent., due to competition from Cleveland, for the average of both large and small seed. Large seed showed an increase in number of grains per ear when competing with small seed, the difference being of doubtful significance. These were the only instances of ear characters being significantly affected.

There is some evidence that the results of competition due to the two factors are expressed at different times. It appears from the data that whereas, in the case of difference in seed size, the effect of competition is apparent during the production of tillers, in the case of a

difference in variety (maturity) no effect is evident until culm development. It has been shown previously that seed size is correlated with differences in very early development. Unequal competition between plants arising from different seed size probably originates, therefore, in an initial difference at germination, as suggested by McMillan.* Unequal competition between the two varieties used in this experiment is first apparent at a later stage of development. The strongly competing variety is the later maturing one, with a larger tiller number. In this instance competitive ability may develop as a result of greater root development which would be compatible with a larger tiller number, but which would not become effective until tiller formation had been in progress for some time.

Both the factors investigated have significant effects upon ear number. Large seed in competition with small seed shows increases in ear number. This follows an early increase in tiller number, suggesting that the greater ear number is the result of an initial advantage in general vigour. The unequal competitive ability of the two varieties is expressed in a different way. The late variety, which in competition with the early variety possesses the competitive advantage in respect to ear number, does not show a corresponding increase in tiller number. In fact, there is a slight reduction, which, however, is not statistically significant. In this instance the increase in ear number results from a higher survival rate of tillers rather than an increase in number of tillers.

From the point of view of plant selection, yield is the most important character examined. It is significantly changed by both types of competition. When small seed and large seed were sown in competition, the yield from small seed was reduced, in comparison with the control plots, by 19.9 per cent., and that from large seed increased by 36.6 per cent. Also, when the varieties Early Bird and Cleveland were sown in competition, the yield of Early Bird was reduced by 23.1 per cent. and that of Cleveland increased by 23.2 per cent. These changes in yield are accounted for by the changes in ear number rather than in weight of grain per ear.

These results represent mean values from 135 plants. It follows that individual plants in mixed populations would often suffer still greater effects as a result of similar competition.

It is clear that in many wheat crosses, sown at close spacings, particularly in the early segregating generations, the actual yield of an individual plant may bear very little resemblance to the potential yield of its genotype.

It has long been recognized by wheat breeders that single plant selection for yield, in F_2 in particular, is not effective, and their breeding programmes have been adapted accordingly. In the earlier generations, elimination of plants of undesirable type in respect to the characters ancillary to yield is usually practised, and selection for yield is left until later generations. It is obvious, however, that any method which would make single plant selection reliable would considerably improve wheat breeding technique. This improvement would result not only from the greater effectiveness of selection, whenever made, but also by enabling selections for yield to be made earlier in the programme.

* McMillan, J. R. A.—*J. Coun. Sci. Ind. Res.* (Aust.), **8**: 1-7 (1935).

It would reduce the number of progenies carried into later generations, and enable the plant breeder to use larger F_2 populations, or to utilize more crosses. In each case the probability of obtaining the desired combinations of ancillary characters and yielding ability would be increased.

Several possible methods of improving the effectiveness of single plant selection are apparent from the results obtained.

Firstly, it would appear from the data presented in respect to effect of seed size that much of the variation due to interplant competition could be eliminated by grading the seed according to size or weight, and sowing only seed of approximately the same weight in one plot. This would not, of course, overcome the unequal competition between plants resulting from unlike genotypes.

Secondly, all competition between plants could be eliminated by using a much wider spacing than at present adopted. This would result, however, in dissimilarity from normal field conditions. It is necessary to determine which is the greater of the two sources of error.

A third method whereby the influence of inter-plant competition might be partially overcome is the use of statistical correction. In this experiment, when Early Bird and Cleveland were sown in competition, their values of average weight per grain were respectively 38 and 39 mg. approximately. In the control plots Early Bird gave a value for average weight per grain of 41 mg. and Cleveland 38 mg. Selection for high values of weight per grain in the competition plots would not have been effective in selecting the genotype favouring this character in a pure line, whereas, knowing the effect upon average weight per grain of competition from late maturing genotypes, a statistical correction applied to the earlier maturing plants would have assisted in differentiating the genotypes for different average weights per grain.

Experiments to investigate the possibilities of these methods are in progress.

5. Conclusions.

It is concluded that unequal competition between adjacent plants in heterogeneous wheat populations sown at approximately field spacings may occur as the result of variation in both initial seed weight and in genotype. The effect is of considerable magnitude and is alone sufficient to make the selection of individual plants for yielding ability in segregating generations unreliable. Methods devised to improve the efficiency of single plant selection should take this source of variation into account.

6. Acknowledgments.

The authors wish to record their appreciation of the collaboration of Mrs. Calvert, Biometrician in the Council, and of officers of the Section of Plant Genetics of the Division of Plant Industry.

PLATE 1.

(The Internal Lacquering of Tinplate Containers for Foods.
See Page 16.)

CANS WHICH CONTAINED FISH PRODUCTS FOR 3 MONTHS.

Columns (from left to right).—Australian salmon, crayfish, tuna.

Rows (from top to bottom).—Anodic oxide film in ammonia solution. Anodic oxide film in sodium aluminate solution. Chemically produced protective film. Plain can.

PLATE 2.

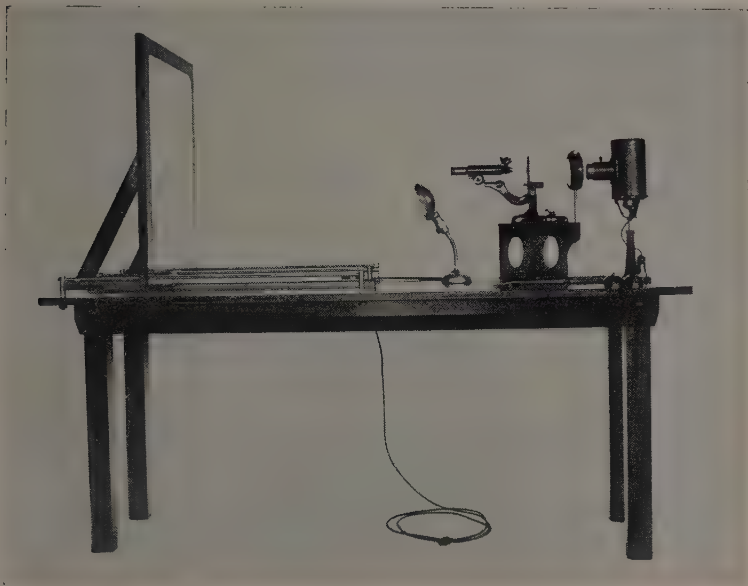
(The Internal Lacquering of Tinplate Containers for Foods. See Page 16.)

FIG. 1.—Plain cans (above) and chemically-treated cans (below) which contained (from left to right) sausages, peas, and onions for 3 months.

FIG. 2.—Cans subjected to weathering test. From left to right.—Externally lacquered can, chemically-treated can, plain can.

PLATE 3.

(A Modified Apparatus for Fish Scale Reading. See page 57.)



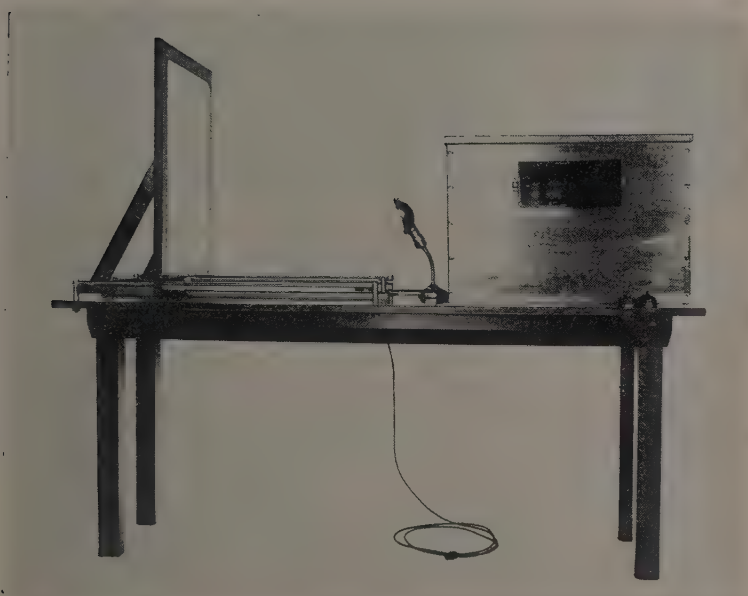
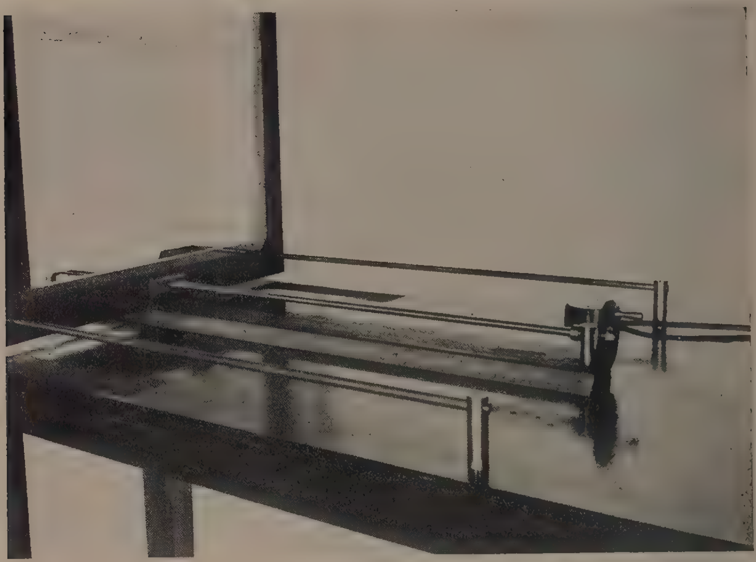


FIG. 1 (above).—Full equipment without housing to microscope.
FIG. 2 (below).—Full equipment with housing.

PLATE 4.

(A Modified Apparatus for Fish Scale Reading. See page 57.)



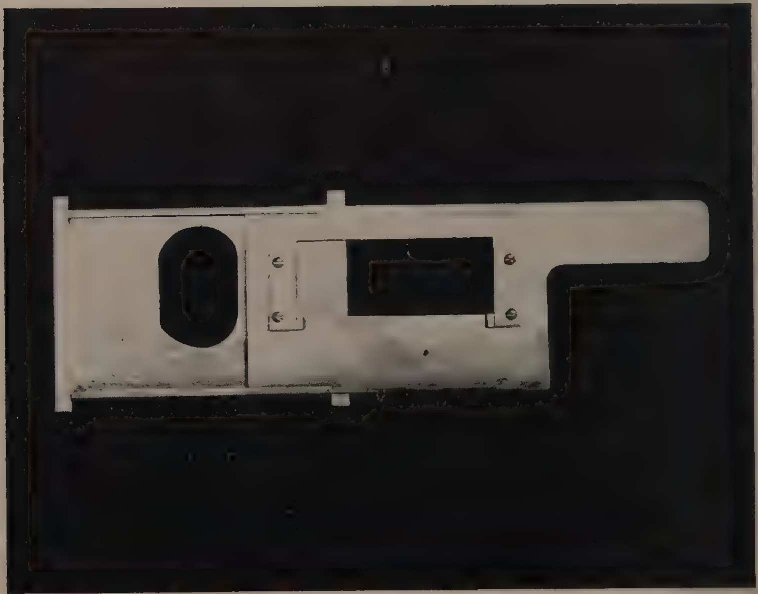


FIG. 1 (above).—Detail to show rods upon which the screen slides, worm drive and wheel at centre, metre rule and the pointer on the screen.

FIG. 2 (below).—Slide holder for attachment to microscope stage.

NOTES.

Australian Vitamin-Rich Fish Oils—A Preliminary Note.

(*Contributed by E. J. Ferguson Wood, B.A., M.Sc.* and C. C. Kuchel, B.Sc.†*)

In the past, most of the cod liver oil used in Australia was imported from Norway, and now that this source of supply has been cut off, a study of Australia's own fish oil resources has become important. Some preliminary results on the liver oil of the yellowtail (kingfish) are given below. In addition, attention is being given to other varieties—e.g., mullet, tuna, and barracouta. Due attention is being paid to the consideration that the oil should be of such quality that its production will continue to be economic in times of peace.—Ed.

Samples of livers frow Yellowtail (*Seriola dorsalis*), known in New South Wales as Kingfish, produced about 10 per cent. of oil of excellent colour and quality. Vitamin tests carried out by the Commonwealth Serum Laboratories, Parkville, gave vitamin A as about 42,000 International Units per gramme using 1,600 as the conversion factor, and 9,000 International Units per gramme of vitamin D.‡

The method used for extraction was to steam the minced livers at 175°F. for ½-hour with 1 per cent. caustic soda and to extract the oily layer with petroleum ether, drying with calcium chloride, and finally distilling off the ether.

A Sharples super-centrifuge is being tried for recovery of oil from the mother liquor, and the experiments are not yet complete.

The results to date, however, show that the yellowtail possesses a liver with an easily extracted oil of high vitamin potency as regards both vitamins A and D. The liver oil is about 36 times as potent as cod liver oil in vitamin A, and 110 times as strong in vitamin D, and could, therefore, be diluted with peanut or other oils for use as medicinal oil in emulsions, &c.

Tuna Fishing Tests.

If any appreciable extra supply of surface swimming Australian fish is to be secured quickly, it must be by the method of capture known as trolling (primarily for tuna, but also for barracouta and possibly other species), that is, by trailing behind a moving boat lines with hooks to which lures are attached. Other methods, such as the purse-seine and live-bait, require specialized and costly vessels not yet used in Australia on a commercial scale.

In order to examine the possibilities of trolling for tuna, arrangements have recently been made with the owners of two suitable Tasmanian fishing boats—the *Weerutta* and the *Jean Nichols*—for the Council to carry out trials over a period of four months. The Council will guarantee agreed-upon financial returns for the boats; fish-canning firms have undertaken to take the catch at an agreed price for canning purposes.

* An officer of the Council's Division of Fisheries.

† An officer of the Council's Division of Food Preservation and Transport.

‡ The Commonwealth Serum Laboratories state that, as the work is still in the early stage, these figures should be accepted with reserve and that they need confirmation from more exhaustive tests.

Fisheries Conference, Melbourne, November, 1940.

The Council recently convened a Fisheries Conference which met in Melbourne towards the end of November last. The meeting was representative of State Fisheries Departments, the Council, and commercial fishing interests.

The Conference was called as the Council felt that it was desirable to bring together interested parties to discuss the whole position as regards the future development of the industry, particularly as the demand for canned fish for the fighting services and for the general public is large and still growing and should give a stimulus for fisheries development. In fact, the urgency of the situation seemed to demand the formation of a definite plan by which the greatest use could be made of existing data.

The matters set down for discussion, therefore, included the different varieties of edible fish, equipment, by-products, processing methods, fishing vessels, and shore organizations. It was also hoped that the Conference would devise machinery to bridge the gap between investigational work and its immediate industrial application.

The Chief of the Council's Fisheries Division (Dr. H. Thompson) pointed out that the main work of his Division to date had been the evaluation of pelagic fishing possibilities in south-eastern waters. He indicated that there was a considerable possibility of a large industry being developed as regards tuna and pilchards. He saw no reason why the tuna industry should not ultimately become as large as the industry in California, and Australian pilchards could readily replace the imported sardine. Barracouta were placed third on the list of pelagic fish capable of immediate development. Salmon were abundant at times, but it was doubtful if they could stand up to intensive fishing, though there was no apparent reason why they should not support a larger industry than at present established. Mullet, with a still more extensive littoral and estuarine habitat than salmon, had been overfished and already appeared to require conservation. Dr. Thompson concluded his remarks by discussing work on methods of capture on which his Division had specialized in recent years. He also drew attention to the need for boat building and the provision of cold storage and sharp freezing depots at key points around the coast.

After giving detailed consideration to the general question of the development of Australian pelagic fisheries, the meeting resolved that a Fisheries Development Committee should be set up for this purpose under the aegis of the Department of Supply and Development and representative of the Council and the fishing industry, and maintaining close liaison with State Fisheries Departments*.

Cattle Tick Investigations.

The Commonwealth Department of Health, which is concerned with the administrative measures involved in the control of the cattle tick pest in Australia by quarantine &c., has recently pointed out that the Council could help by carrying out investigations aimed at the obtaining of further detailed information on which additional control measures and modifications might be based.

* Action on this recommendation is being deferred pending the results of an inquiry the Tariff Board is conducting into the fishing industry.

In particular, this request involves a detailed examination of the life-cycle of the non-parasitic stage of the tick, and particularly the influence of temperature; the effect of adjuvants on the efficiency of the dips is also involved.

It has now been arranged that much of this work will be carried out by a former officer of the Commonwealth Prickly Pear Board (Mr. L. F. Hitchcock), who will be located in Brisbane where State authorities have kindly made available the necessary facilities. Mr. Hitchcock is now an officer of the Council's Division of Economic Entomology.

Pasture Investigations in Queensland.

Pastoral interests in Queensland have for some time past been urging the Council to establish in that State at least one of its major activities related to the pastoral industry. It seemed that one of the most likely fields of activities concerned pasture research, and, with the strengthening of the Council's agrostological team of investigators by the appointment of Dr. J. G. Davies and others some years ago, it became possible to give serious consideration to the Queensland proposals.

Dr. Davies (Senior Agrostologist of the Division of Plant Industry) spent some months in Queensland and submitted a report on the pastures of the coastal and sub-coastal areas of the State. This report emphasized that the limitation to stock raising in Queensland lies in the low nutritive value of the pastures over long periods of the year. A passage from its conclusion reads as follows:—

> "The main deficiency is that of protein; associated with it—more especially on natural pastures—is mineral deficiency; but if the problem of protein deficiency is solved then the problem of mineral deficiency will also be solved. It is again urged that the search for legumes should be intensified by providing adequate personnel and facilities for enthusiastic and prolonged investigation of both pasture and crop legumes. There is already, because of the keenness and enthusiasm of three or four individuals, enough evidence that this search will be successful. Success will transform the pasture outlook of coastal Queensland and New South Wales from one of doubtful stability to one of sound practical development".

The report also discusses a programme of research involving the erection of a laboratory in Queensland. These matters have now been discussed by the Executive Committee with the Council's Queensland State Committee and other authorities.

A small Committee representative of the Council and the Queensland Department of Agriculture and stock and of Queensland graziers was then set up to give detailed consideration to an appropriate programme of research and the laboratory and other facilities involved. This Committee met towards the end of November last and its recommendations are now under consideration.

The Committee considers that research directed to the alleviation and solution of the problem of protein deficiency and the present deterioration of the pastures with which the subsidiary problems of mineral deficiency are associated will involve:—

(1) The study of the productivity and nutritive value of natural and of sown pastures in the summer rainfall belt, and this will include the value of both native and introduced grasses and herbage plants.

(2) The search for pasture legumes to grow in the various soil and climatic zones and the incorporating of such legumes into pasture swards.

(3) Grazing and management studies on improved pastures and on natural pastures.

(4) The development of grain and fodder legumes both for their direct value as protein and mineral rich foods, especially in times of drought; and their indirect value in enhancing soil fertility.

(5) The study of fodder conservation from pastures and crops and the storage of fodder reserves as hay silage or grain.

(6) The delineation of pasture zones based in soil and climatic factors.

The Committee considers that, in order effectively to undertake research on the above programme, the following would be required:—

(*a*) A central laboratory to be located in the grounds of the University of Queensland.

(*b*) As an indispensable adjunct to the laboratory, an area of 50 to 60 acres of high quality arable land within 5 or 6 miles of the laboratory and an area of 400 to 500 acres in typical cattle country within easy reach of Brisbane.

This latter area would enable pasture types to be tested under grazing conditions. Sub-stations for the further testing of conclusions would also be involved. In this connexion, however, existing agricultural experimental stations of Queensland organizations would no doubt be available.

Biometrics—Appointment of Mr. E. A. Cornish.

Following the resignation of the Council's senior biometrical officer (Mrs. J. Calvert, née Allan), Mr. E. A. Cornish, M.Sc., B.Agr.Sc., has been appointed to fill the vacancy. After graduating from the University of Melbourne in 1931, Mr. Cornish was appointed to the staff of the Waite Agricultural Research Institute in 1932; he subsequently spent a year in England under Professor R. A. Fisher at the University College, London.

Mr. Cornish will have his future headquarters in Melbourne as being a central location for the calls which will be made on him from practically all the Council's Divisions.

Viticultural Research at Merbein—Immediate Programme.

At a meeting of the Executive Sub-committee of the Advisory Committee of the Council's Merbein Station, consideration was given to the programme of the Station in relation to war conditions. After reviewing the work in hand, the Sub-committee recommended the following general programme:—

(i) That two long-dated viticultural investigations, dealing with fertilizers and trellising, and the special field plots on the Station vineyard be continued; also the special investigations dealing with the intake of nutrients to the sultana.

(ii) That otherwise viticultural investigations be limited to records of commercial value to the industry; and in this respect the seasonal maturation studies and yield estimates were considered most important.

(iii) That the assistance rendered to the packing houses in connexion with the processing and treatment of the dried fruit be continued on present lines. The necessity for extension of investigations dealing with the seeding of raisins was stressed, in view of the opportunity to replace imported dates with this product.

(iv) That drainage investigations be continued, on account of their importance in soil preservation and in preparing for post-war capital expenditure. In particular, the investigation sought by the Curlwaa growers, in reference to methods of draining settlements on the river flat soil types, should be carried out.

It was also agreed that the further expansion of irrigation would be associated with the development of pastures and fodders, and it was decided that as soon as practicable the pasture plots on the Merbein Station should be extended to the soils of the heavy river flat types, as these soils were commonly used for pastures and presented greatest difficulties in development.

The experience of the Station, in devising and adjusting the various dipping solutions used in drying grapes, has proved of great value with the advent of war. For instance, growers have been advised of various methods of conserving potash supplies. A means of using an extract of vine ash for dipping sultanas was described in a previous issue of this *Journal* (**13**: 181, 1940). The addition of an efficient wetter to dipping solutions has also made it possible to dip grapes effectively with reduced quantities of potash, the wetter giving more efficient drainage and greater uniformity in the results; it is now possible to dip at least 15 tons of dried fruit per cwt. of potash.

Similarly, cottonseed oil has now been successfully incorporated in the dips instead of olive oil, the supply of which is restricted. Another important innovation is a dried fruit wash—a casein paraffin emulsion with potassium oleate, which effectively reconditions sticky fruit and gives it the freedom desired in pressed packs. The use of this emulsion has enabled satisfactory marketing of damaged berries which formerly had a low value owing to massing and sticking after final processing.

Recent Publications of the Council.

Since the last issue of this *Journal,* the following publications of the Council have been issued:—

Bulletin No. 134.—"Studies on Bovine Mastitis, I.—Study of an Experimental Herd," from the Division of Animal Health and Nutrition.

This Bulletin records the preliminary results of the study of an experimental dairy herd in an attempt to form a basis on which scientific investigation of the cause and control of bovine mastitis may be built.

The report deals with the examination of the results obtained in the experimental herd of 30 animals during the first two lactation periods. It is written as a scientific monograph for scientific workers in the subject, but nevertheless some results of interest and importance to administrative officers and dairy farmers are already apparent from these preliminary studies.

As the most common form of mastitis in dairy cows is usually regarded and treated as a contagious disease, an experimental herd was established by the selection of non-pregnant heifers and the herd was kept in perpetual quarantine. Despite these precautions the streptococcus which causes the most common form of mastitis made its appearance and caused several cases of clinical mastitis. Most of the cows harboured the streptococcus for short periods in one or more quarters of the udder during the period under review, but in none did the infection become chronic. Other bacteria capable of causing mastitis also made their appearance in the herd and produced cases of the disease. It was found that some species of bacteria commonly invading the udder of dairy cows are capable of causing more damage than others. All the infections had a similar distribution throughout the herd; that is, they were similar in their occurrence and spread. Infectivity appeared to be very much the same in all these species of bacteria, but the capacity to damage the tissues varied with the species.

These systematic studies on the bacteriology of the cow's udder are more complete than most studies that have been made in other parts of the world. The knowledge thus gained is essential for a sound foundation for the study of the diseases which occur in the udders of dairy cows as the result of bacterial infections. The report is the first of a series of publications to be made on the subject.

Bulletin No. 135.—"Investigations on the Storage of Jonathan Apples grown in Victoria," by S. A. Trout, M.Sc., Ph.D., G. B. Tindale, B.Sc.Agr., and F. E. Huelin, B.Sc., Ph.D.

This report discusses the various factors associated with wastage in Jonathan apples from Victoria during storage. Such wastage is considerable, as the Jonathan apple, which ranks next in importance to the Sturmer Pippin as an export variety, is subject to a number of disorders during, and shortly after removal from, cool storage, and, moreover, rapid deterioration of eating quality occurs unless the fruit is placed in comparatively low temperatures soon after picking.

The important factors influencing the keeping quality of the fruit are: maturity of the fruit at time of picking, seasonal and growing conditions, size of the fruit and of the crop, handling treatment, pre-storage conditions after picking, storage temperature, composition of the storage atmosphere, and duration of storage.

The respiratory activity of the fruit after picking is the most reliable index of its maturity, but its use is not of commercial application. The ground colour, i.e., the colour of the unblushed portion of the fruit, is a fairly reliable index of the maturity, and a coloured chart is included in the Bulletin to show the most satisfactory stage at which to pick the fruit.

Because of the possible development of low temperature disorders, prompt cooling of Jonathan apples to 32°F. immediately after picking is not recommended, but cooling to 36°F. to 45°F. should result in less wastage and the maintenance of better condition during overseas transport than by leaving the fruit in the packing shed prior to shipment. A temperature of 34°F. seems to be satisfactory for the overseas transport of Jonathan apples from Victoria, but in local storage the maintenance of condition and freedom from wastage is probably best obtained by holding the fruit at 36°F. to 37°F. until mid May, prior to storage at 32°F.

Wastage in Jonathan apples has usually exceeded 10 per cent. by the end of September, but the apples can be held in a better condition if stored in an atmosphere containing 5 per cent. of carbon dioxide and 16 per cent. of oxygen at 36°F., than if stored in air at the same temperature.

The investigations described were carried out by officers of the Victorian Department of Agriculture and of the Council working in co-operation.

Pamphlet No. 103.—" An Examination of Some Australian Hardwood Charcoals with Special Reference to Their Suitability for Charcial Gas Producers," by J. N. Almond, B.Sc., B. M. Holmes, M.Sc., and Enid C. Plante, B.Sc.

In December, 1939, the Department of Supply and Development drew up a provisional specification for wood charcoal, designed to act as a guide to purchasers of charcoal for mobile producers. The present Pamphlet describes the results of applying the standard tests set out in the provisional specification to a number of the commoner Australian hardwood charcoals. The charcoals were examined for moisture content, ash content, volatiles content, calorific value, and cleanliness, and almost without exception they were found to comply with the specifications. Since the samples tested were drawn from ordinary commercial charcoals burnt by a variety of different methods, it may be concluded that most commercial charcoals will give satisfactory results in well-designed producer gas vehicles.

The provisional specification is given in an appendix to the Pamphlet, which may be regarded as an examination of the specification as much as of the charcoal itself.

Forthcoming Publications of the Council.

At the present time the following future publications of the Council are in the press:—

Bulletin No. 136.—"Experimental Studies of Ephemeral Fever in Australian Cattle," by I. M. Mackerras, B.Sc., M.B., Ch.M., and M. J. Mackerras, M.Sc., M.B.

Bulletin No. 137.—"A Soil Survey of the Red Cliffs Irrigation District, Victoria," by G. D. Hubble, B.Agr.Sc., and R. L. Crocker, B.Sc.

Bulletin No. 138.—"The Economic Biology of Some Australian Clupeoid Fish," by M. Blackburn, M.Sc.

Bulletin No. 139.—"The Soils of Tasmania," by C. G. Sephens, M.Sc., A.A.C.I.

Bulletin No. .—"Report on the Graphintegrator and Other Papers," by D. M. Myers, D.Sc.Eng., W. K. Clothier, B.Sc., B.E., and L. U. Hibbard, B.Sc.

Pamphlet No. 104.—"The Australian Tunas," by D. L. Serventy, B.Sc., Ph.D.

Pamphlet No. 105.—"The Biology and Cultivation of Oysters in Australia, 1.—Some Economic Aspects," by G. L. Kesteven, B.Sc.

Pamphlet No. 106.—"Agricultural Features of the Australian Potato Industry," by J. G. Bald, M.Agr.Sc., Ph.D.

Pamphlet No. .—"Studies on some Ectoparasites of Sheep and their Control. 1. Observations on the Bionomics of the Sheep Ked (*Melophagus ovinus*)," by N. P. H. Graham, B.V.Sc., and K. L. Taylor, B.Agr.Sc. 2. "Preliminary Observations on the Use of Certain Arsenical Dipping Fluids," by M. R. Freney, B.Sc., M. Lipson, B.Sc., and N. P. H. Graham, B.V.Sc. 3. "Chemical Observations on Commercial Powder Sheep Dips with Special Reference to their Arsenic Content," by M. Lipson, B.Sc.

H. E. Daw, Government Printer, Melbourne.

MEMBERS OF STATE COMMITTEES

New South Wales

Professor R. D. Watt, M.A., B.Sc. (*Chairman*).
E. C. Andrews, Esq., B.A., F.G.S.
Professor E. Ashby, D.Sc.
Professor Sir Henry E. Barraclough, K.B.E., V.D., B.E., M.M.E., M.Inst.C.E., M.I.Mech.E.
Professor W. J. Dakin, D.Sc.
Professor J. C. Earl, D.Sc., Ph.D., F.I.C.
W. R. Hebblewhite, Esq., B.E.
C. H. Hoskins, Esq.
The Hon. Sir Norman W. Kater, Kt., M.L.C., M.B., Ch.M.
F. Leverrier, Esq., K.C., B.A., B.Sc.
Sir Frederick McMaster.
J. Merrett, Esq.
R. J. Noble, Esq., B.Sc. (Agr.), M.Sc., Ph.D.
E. D. Ogilvie, Esq., B.A.
A. R. Penfold, Esq., F.I.C., F.A.C.I.
Professor J. D. Stewart, M.R.C.V.S., B.V.Sc.
F. J. Walker, Esq.
Lt.-Col. H. F. White, C.M.G., D.S.O.

Victoria

Russell Grimwade, Esq., C.B.E., B.Sc. (*Chairman*).
Professor W. E. Agar, M.A., D.Sc., F.R.S.
W. Baragwanath, Esq.
N. K. S. Brodribb, Esq., O.B.E., F.I.C.
G. S. Colman, Esq., C.B.E.
Sir Herbert W. Gepp, Kt., M.Aust.I.M.M., M.Am.I.M.M.
G. G. Jobbins, Esq., M.I.E.E., M.I.E.Aust.
Sir Dalziel Kelly, Kt., LL.B.
Professor W. N. Kernot, B.C.E., M.Mech.E., M.Inst.C.E.
Emeritus-Professor Sir Thomas R. Lyle, M.A., D.Sc., F.R.S.
H. A. Mullett, Esq., B.Agr.Sc.
B. Perry, Esq.
F. J. Rae, Esq., B.A., B.Sc., B.Agr.Sc.
W. E. Wainwright, Esq., A.S.A.S.M., M.Aust.I.M.M., M.Am.I.M.M.
L. J. Weatherly, Esq., M.A.
Professor H. A. Woodruff, B.Sc., M.R.C.V.S., &c.
Professor W. J. Young, D.Sc.

South Australia

T. E. Field, Esq. (*Chairman*).
A. J. Allen, Esq., A.A.C.I.
E. H. Bakewell, Esq.
C. E. Chapman, Esq., F.I.C.
J. H. Gosse, Esq.
Professor Kerr Grant, M.Sc., F.Inst.P.
Professor T. H. Johnston, M.A., D.Sc.
F. T. Perry, Esq.
Professor J. A. Prescott, D.Sc.
W. J. Spafford, Esq., R.D.A.
L. K. Ward, Esq., B.A., B.E., D.Sc.

MEMBERS OF STATE COMMITTEES—*(continued)*

Queensland

Professor H. C. Richards, D.Sc. (*Chairman*).
Professor H. Alcock, M.A.
J. D. Bell, Esq.
Professor E. J. Goddard, B.A., D.Sc.
V. G. Grenning, Esq.
J. B. Henderson, Esq., O.B.E., F.I.C.
Professor T. G. H. Jones, D.Sc.
A. G. Melville, Esq.
J. F. Meynink, Esq.
Professor J. K. Murray, B.A., B.Sc.Agr.
Professor T. Parnell, M.A.
Professor H. R. Seddon, D.V.Sc.
R. P. M. Short, Esq.
R. Veitch, Esq., B.Sc.Agr., B.Sc.For., F.E.S.

Western Australia

E. H. B. Lefroy, Esq. (*Chairman*).
Professor N. S. Bayliss, B.A., B.Sc., Ph.D.
H. Bowley, Esq., F.A.C.I.
F. G. Brinsden, Esq., M.I.M.M., M.Aust.I.M.M.
W. G. Burges, Esq.
Professor E. De Courcy Clarke, M.A.
Professor G. A. Currie, D.Sc., B.Agr.Sc.
J. D. Hammond, Esq.
P. H. Harper, Esq., B.A.
L. St. J. Jones, Esq.
S. L. Kessell, Esq., M.Sc., Dip.For.
A. L. B. Lefroy, Esq.
Professor G. E. Nicholls, D.Sc., A.R.C.Sc., F.L.S.
L. W. Phillips, Esq., M.Sc., M.Ed.
Professor A. D. Ross, M.A., D.Sc., F.R.S.E., F.Inst.P.
G. L. Sutton, Esq., D.Sc. Agr.

Tasmania

P. E. Keam, Esq. (*Chairman*).
N. P. Booth, Esq., F.I.C.
Professor A. Burn, M.Sc., B.E.
J. W. Evans, Esq., M.A., D.Sc.
F. H. Foster, Esq., M.H.A., B.M.E., A.M.I.E.Aust.
F. W. Hicks, Esq.
Professor A. L. McAulay, M.A., B.Sc., Ph.D., F.Inst.P.
D. O. Meredith, Esq., A.Inst.M.M., M.I.E.Aust., M.A.C.S.
A. K. McGaw, Esq., C.M.G.
W. E. Maclean, Esq., M.Inst.C.E., M.I.E.Aust.
F. H. Peacock, Esq.
The Hon. R. O. Shoobridge, M.L.C.
S. W. Steane, Esq., B.A., F.R.G.S.